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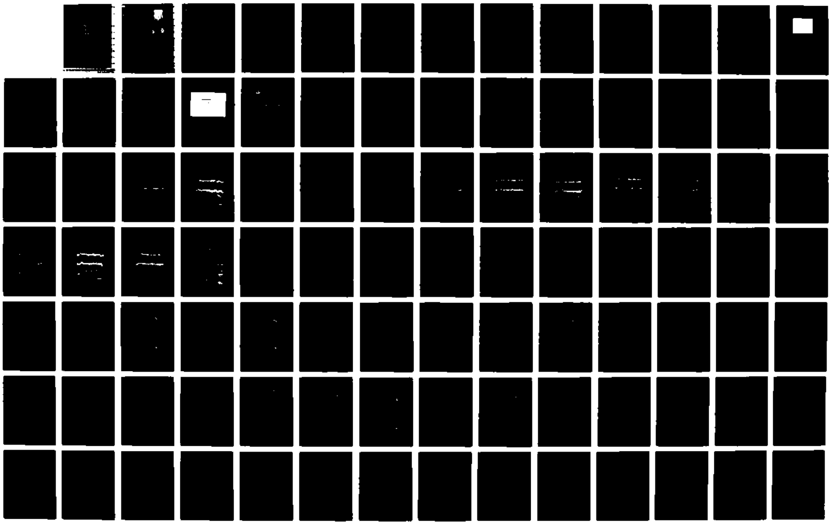

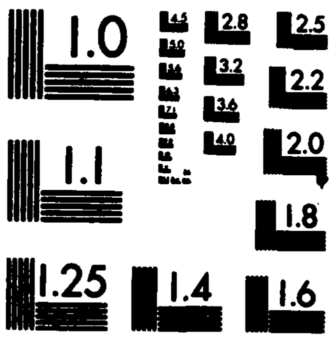

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AFWAL-TR-86-3109
VOLUME II

EXPERIMENTAL INVESTIGATION OF THE SHORT-PERIOD REQUIREMENTS OF MIL-F-8785C

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FLIGHT DYNAMICS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
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WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6553

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An investigation of the short period frequency requirements of MIL-F-8785C was performed using the USAF/TIFS in-flight simulator. Thirty-five evaluations of eighteen configurations were conducted. The experiment examined the minimum frequency boundary at three values of (n/α) for one true airspeed. The experiment included the effects of pilot location and evaluation task. The data indicate that the current requirement is essentially valid. The minimum acceptable frequency boundary may be relaxed, however, when the pilot station is forward of the center of rotation. Also, the phasing between the normal acceleration and pitch rate responses has been shown to be a critical determinant of longitudinal short period flying qualities. The results are analyzed also using the equivalent systems methodology. Keywords:

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FOREWORD

This report is separated into two volumes. Volume I contains the body of the report covering the experiment design, presentation of data, and discussion of the results. Pilot comments, experiment mechanization details, and additional data have been compiled in a series of appendices, contained herein, as Volume II.

TABLE OF CONTENTS

LIST OF SYMBOLS

b	wing span (ft)
C_D	$D/\bar{q}S$, airplane drag coefficient
$C_{D_{(\ )}}$	$= \frac{\partial C_D}{\partial (\ )}$
C_L	$L/\bar{q}S$, airplane lift coefficient
$C_{L_{(\ )}}$	$= \frac{\partial C_L}{\partial (\ )}$
C_ℓ	$\frac{\ell}{\bar{q}Sb}$, airplane rolling moment coefficient
$C_{\ell_{(\ )}}$	$= \frac{\partial C_\ell}{\partial (\ )}$
C_M	$M/\bar{q}S\bar{c}$, airplane pitching moment coefficient
$C_{M_{(\ )}}$	$= \frac{\partial C_M}{\partial (\ )}$
C_n	$N/\bar{q}Sb$, airplane yawing moment coefficient
$C_{n_{(\ )}}$	$= \frac{\partial C_n}{\partial (\ )}$
C_y	$y/\bar{q}S$, airplane side force coefficient
$C_{y_{(\ )}}$	$= \frac{\partial C_y}{\partial (\ )}$
D	airplane drag force (lbs)
$\bar{c}$	mean aerodynamic chord (ft)
$\frac{dC_M}{dC_L}$	rate of change of C_m with respect to C_L, static stability
dB	decibels

LIST OF SYMBOLS (Cont.)

F_{as}	centerstick roll force, positive right (lbs)
F_{es}	centerstick pitch force, positive aft (lbs)
F_{rp}	rudder pedal force, positive right pedal (lbs)
(F_{es}/g)	steady-state, longitudinal stick force per "g" (lbs/g)
g	acceleration of gravity, (ft/sec^2)
I_m	imaginary axis
I_{xx}	moment of inertia about body x-axis (slug-ft^2)
I_{yy}	moment of inertia about body y-axis (slug-ft^2)
I_{zz}	moment of inertia about body z-axis (slug-ft^2)
I_{xz}	product of inertia about body xz-axis (slug-ft^2)
$K_{n_{z_e}}$	equivalent normal acceleration transfer function gain (g/lbs)
K_{q_e}	equivalent pitch rate transfer function gain (deg/sec/lbs)
ℓ	airplane rolling moment (ft-lbs)
L	airplane lift force (lbs)
$L_{(\ )}$	$= \frac{1}{mV} \frac{\partial L}{\partial (\ )}$
ℓ_p	axial distance from airplane instantaneous center of rotation to pilot station (feet)
M	airplane pitching moment (lbs-ft)
$M_{(\ )}$	$= (\frac{1}{I_{yy}}) \frac{\partial M}{\partial (\ )}$
m	airplane mass (slugs)
N	airplane yawing moment (ft-lbs)
n_z	normal acceleration at c.g. (g)
n_L	normal load factor (g)
$\Delta n_{z_{ss}}$	steady-state change in normal acceleration (g)

LIST OF SYMBOLS (Cont.)

(n/α)	steady-state normal accleration change per unit angle of attack change (g/radians)
$(n/\alpha)_e$	$= (V/g)(1/\tau_{\theta_2})_e$
q	pitch rate (deg/sec)
$\bar{q}$	dynamic pressure, (lbs, ft^2)
R_e	real axis
S	wing area (ft^2)
s	laplace operator (sec^{-1})
T_2	time-to-double amplitude (sec)
V	true airspeed (ft/sec)
V_i	indicated airspeed (knots)
W	airplane weight (lbs)
α	airplane angle-of-attack (radians)
β	airplane angle-of-sideslip (radians)
γ	flight path angle (radians)
δ_a	aileron deflection
δ_{as}	centerstick roll deflection, inches
δ_e	elevator deflection
δ_{e_c}	commanded elevator deflection
δ_{es}	centerstick pitch deflection, inches
δ_r	rudder deflection
δ_z	(TIFS) direct lift flap deflection, deg
δ_{rp}	rudder pedal deflection, inches
ζ_{dr}	dutch roll mode damping ratio
ζ_{ph}	phugoid mode damping ratio

LIST OF SYMBOLS (Cont.)

ζ_{sp}	short period mode damping ratio
ζ_{ϕ}	damping ratio of second order term in bank-angle to aileron transfer function
θ	aircraft pitch angle
θ_c	commanded pitch angle, degrees
θ_e	$= (\theta_c - \theta)$
ρ	air density (slugs/ft^3)
$\tau_{n_{z_e}}$	equivalent normal acceleration time delay (sec)
τ_{q_e}	equivalent pitch rate time delay (sec)
τ_{θ_2}	airplane lead time constant in pitch transfer function, (sec)
ϕ	airplane bank angle
ϕ_c	commanded bank angle
ϕ_e	$= (\phi_c - \phi)$
ω_B	bandwidth frequency of Neal-Smith criterion (rad/sec)
ω_{BW}	bandwidth frequency of bandwidth criterion (rad/sec)
ω_n	natural frequency, rad/sec
$\omega_{n_{sp}}$	short period mode natural frequency, rad/sec
$\omega_{n_{sp_e}}$	equivalent short period frequency, rad/sec
ω_{dr}	dutch roll mode natural frequency, rad/sec

LIST OF ABBREVIATIONS

ADI	attitude direction indicator
AFWAL	Air Force Wright Aeronautical Laboratories
AGL	above ground level
BIUG	Background Information and User's Guide
CAP	control anticipation parameter
c.g.	center of gravity
c.r.	center of rotation
e	exponential
FFT	fast Fourier transformation
fps	feet per second
ft	feet
HUD	head-up-display
KIAS	knots, indicated airspeed
lbs	pounds
mils	milliradians
msec	milliseconds
MSL	mean sea level
PIO	pilot induced oscillation
PR	pilot rating
rad	radians
rps	radian per second
USAF	United States Air Force

LIST OF ABBREVIATIONS (Cont.)

VFR	visual flight rules
VMC	visual meteorological conditions
VSS	variable stability system
$(\dot{\ })$	first derivative with respect to time $\left(\frac{d(\ )}{dt}\right)$
$(\ )_o$	initial ( )
$(\ )_{eff}$	effective ( )
$(\ )_e$	equivalent ( )

Appendix A

TOTAL IN-FLIGHT SIMULATOR AIRCRAFT

This experimental investigation was conducted using the six-degree-of-freedom, in-flight simulation capability of the USAF/Total In-Flight Simulator (TIFS) aircraft. The TIFS airplane (Figure A-1) is a highly modified NC-131H. The TIFS was modified and is operated by Calspan under USAF contract. The most significant feature of the TIFS aircraft is the separate evaluation cockpit located forward and below the normal (safety pilot) cockpit of the NC-131H.

This evaluation program utilized the model-following simulation capability of the TIFS aircraft. When flown by the evaluation pilot during the evaluation, the pilot control commands are fed as inputs to the model computer which calculates the aircraft response to be reproduced. These responses, along with TIFS motion sensor signals, are used to generate feedforward and response error signals, which drive the six controllers on the TIFS (Figure A-2). The result is a high fidelity reproduction of the motion and visual cues at the pilot position of the model aircraft. More detailed descriptions of the TIFS can be found in Reference 1 and 2.

This experiment made use of the following features inherent in the TIFS aircraft:

- Independent control of all six forces and moments by use of elevator, aileron, rudder, throttle, direct lift flaps and side force surfaces.

- Longitudinal and lateral/directional model-following systems to provide the evaluation pilot with motion and visual cues representative of the simulated aircaft.

- Separate evaluation cockpit capable of accepting appropriate pilot controls and displays. An observer, but not a co-pilot, was present in the right hand seat of the evaluation cockpit.

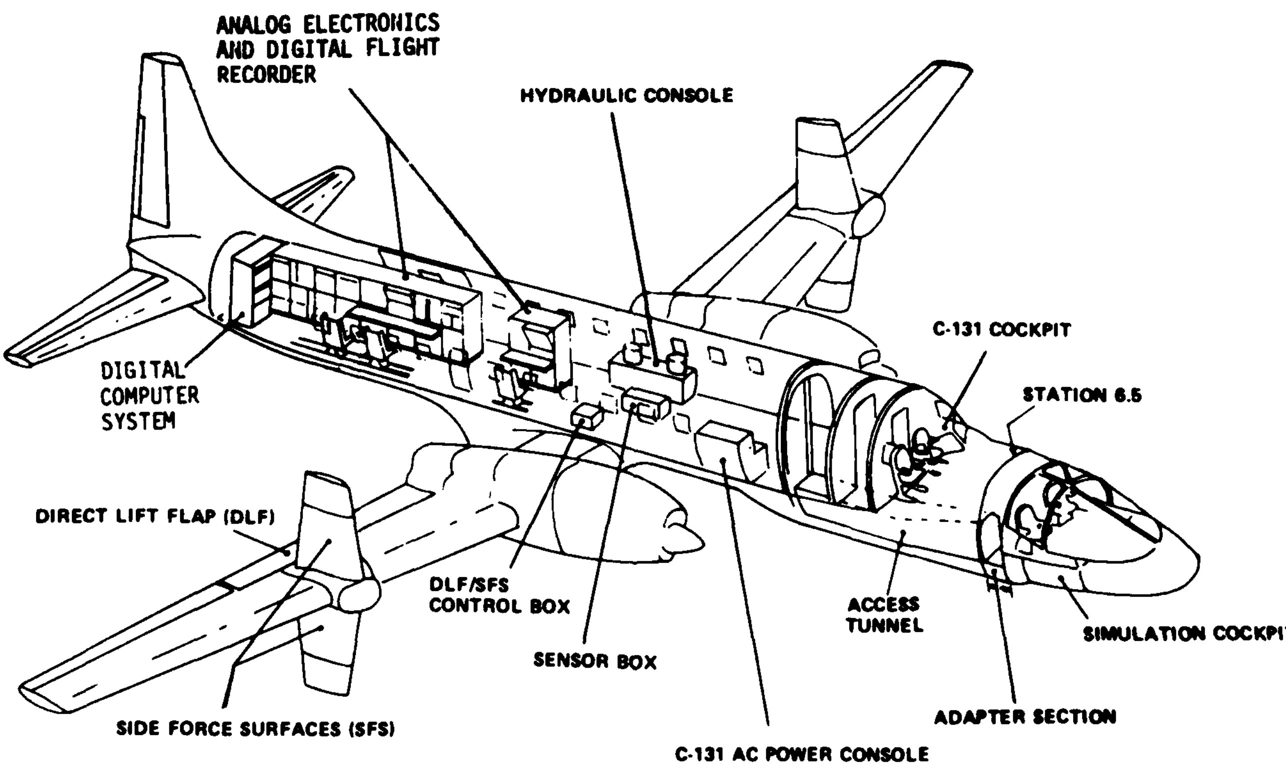


Figure A-1. USAF/CALSPAN TOTAL IN-FLIGHT SIMULATOR (TIFS)

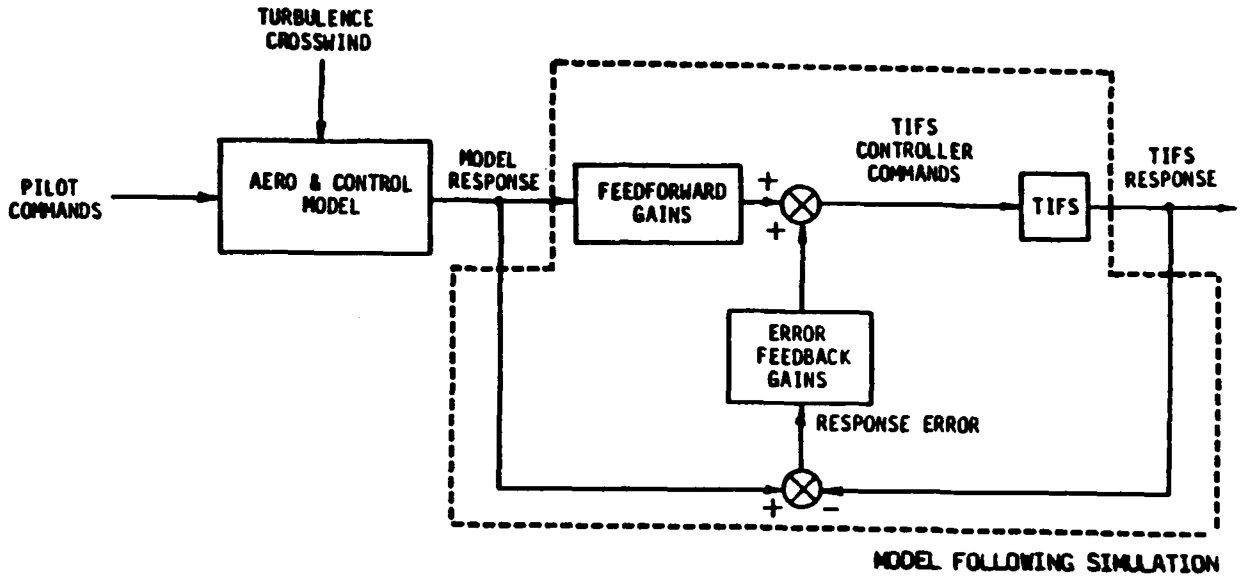


Figure A-2. TIFS MODEL FOLLOWING SIMULATION

- Evaluation cockpit instruments included standard IFR instrument displays featuring an Attitude Direction Indicator (ADI) and a Horizontal Situation Indicator (HSI) as the primary instruments. The vertical and horizontal bars on the ADI were available but not used to display command information for tracking localizer and glide slope, respectively.

- Digital magnetic tape recording system to record control inputs and appropriate aircraft responses.

- Two cassette tape voice recorders for recording evaluation pilot and TIFS crew comments.

The evaluation pilot was seated in the left hand seat of the two place, side-by-side evaluation cockpit. A standard center stick was installed for pitch and roll control. Rudder pedals were available for yaw control. A left hand, throttle quadrant was used for thrust control. The feel system characteristics of these controllers are described in Table A-I. The throttle handle has an adjustable friction level.

The evaluation pilot instrument panel is shown in Figure A-3. Although not shown in this figure, a fixed reticle gunsight was installed directly above the attitude direction indicator on the glare shield. Two head-down, compensatory tracking tasks were mechanized using the attitude direction indicator (ADI). For these tasks, the ADI was disabled from its normal function of displaying actual aircraft attitude. Instead, the display was driven by the error signal between a commanded attitude and the actual attitude of the TIFS. In this manner, a compensatory attitude tracking task was established. The ADI is a standard 3 inch display. The dynamic performance was not measured but the response was sufficiently fast to be considered not a factor.

In this evaluation of short period response flying qualities, the performance capabilities of the TIFS simulator constrained the available evaluation tasks. The approximate normal acceleration limits for the TIFS aircraft at the nominal airspeed for this program are presented in Figure A-4.

TABLE A-I
FEEL SYSTEM CHARACTERISTICS

Pitch:	Centerstick
	±5 inches full throw
	Friction: neglegible
	Breakout: 0.5 lbs
	Gradient: 12.5 lbs/inch (linear)
Roll:	Centerstick
	±3.2 inches full throw
	Friction: negligible
	Breakout: 0.5 lbs
	Gradient: 2.80 lbs/inch (linear)
Yaw:	Pedals
	±3.0 inches full throw
	Friction: neglegible
	Breakout: 5 lbs
	Gradient: 20 lbs/inch (linear)

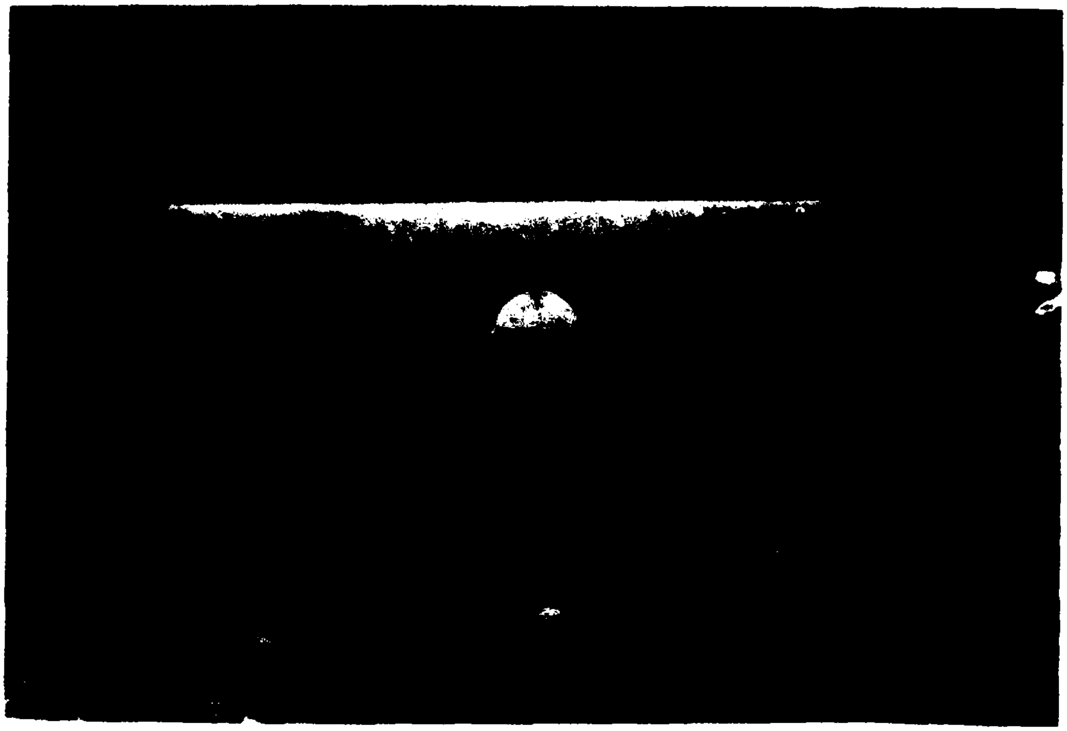


Figure A-3. EVALUATION COCKPIT INSTRUMENT PANEL

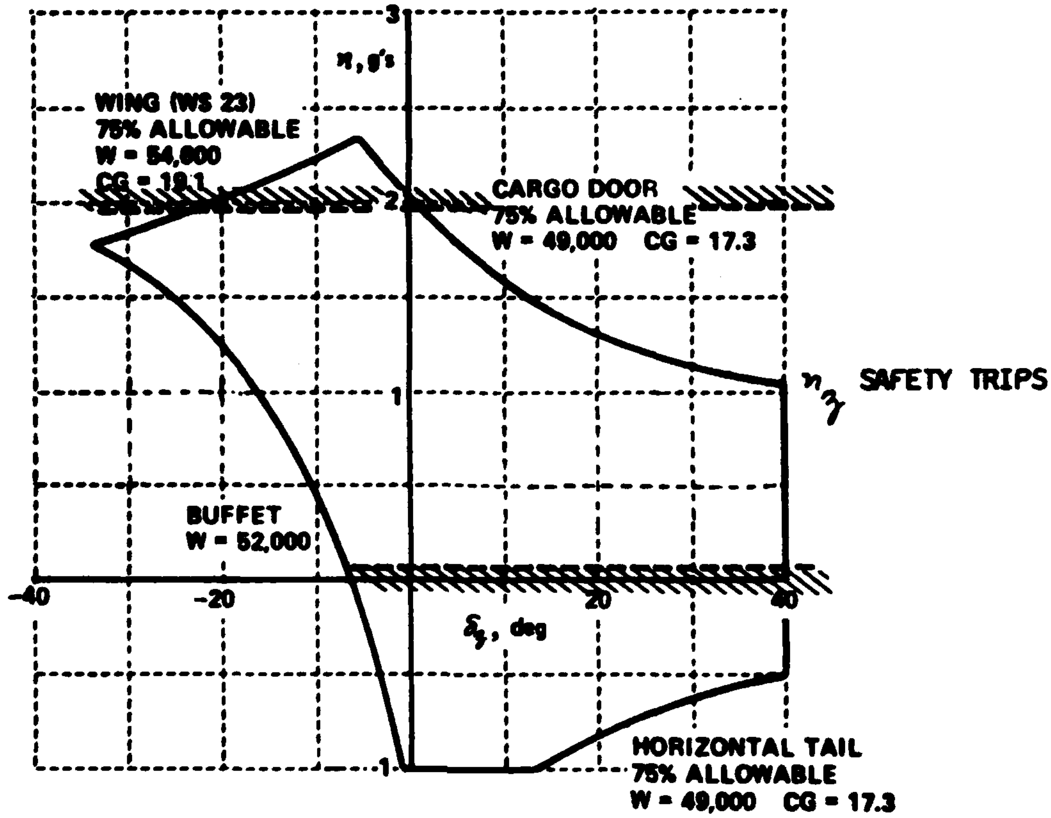
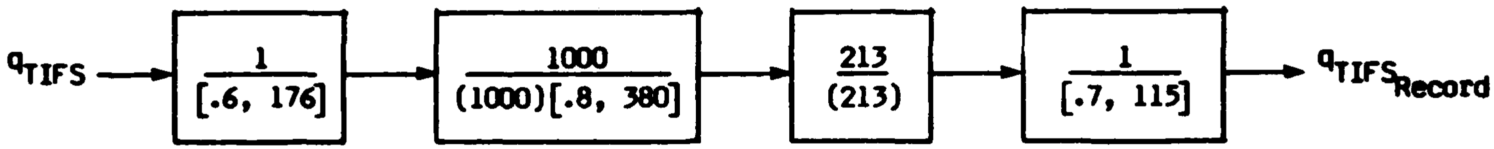
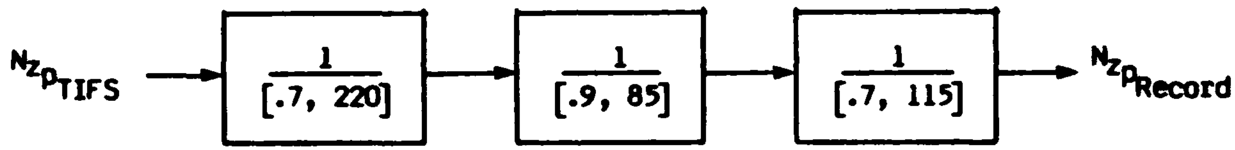


Figure A-4 TIFS APPROXIMATE NORMAL ACCELERATION LIMITATIONS AT 218 KIAS AS A FUNCTION OF DIRECT LIFT FLAP DEFLECTION (δ_z)

Data analysis was performed in Section 5 and 6 of Volume I. Details of this analysis and presentation of the data are given in Appendices C,D and E. Aircraft response parameters in this analysis were exclusively the motion responses of the TIFS aircraft in replicating the model configurations (Figure A-2). Correct analysis must properly account for sensor and signal conditioning filters that are included in the recorded data. The signal conditioning filters and sensor dynamics for the pitch rate and normal acceleration signals are shown in Figure A-5. Recording was performed at 100 samples per second and all signals are filtered by 115 rad/sec anti-aliasing filters.



Pitch Rate



Normal Acceleration at Simulation Cockpit

<u>Short hand notation used:</u>

$(a) \rightarrow (s + a)$

$[\zeta, \omega] \rightarrow [s^2/\omega^2 + 2\zeta/\omega \; s + 1]$

Figure A-5. SCHEMATIC DIAGRAM OF PITCH RATE AND NORMAL ACCELERATION SIGNALS

Appendix B
MODEL DESCRIPTIONS

When the TIFS aircraft is flown by the evaluation pilot in the model-following or fly-by-wire mode, the pilot cockpit control commands are fed as inputs to the onboard model computer which calculates the aircraft response to be reproduced.

The TIFS model computer consists of analog and digital components. For this evaluation, the digital computer capability was used for calculation of the model aerodynamics and kinematic equations. The attitude tracking tasks (Section 4) were also stored in the digital computer. The update rate was 80 hertz.

The analog capabilities of the TIFS model computer were used for implementation of the model control system and scaling and control of the attitude tracking task. The model configurations were implemented by manipulation of the model aerodynamics and control system.

The simulated aircraft was a generic aircraft whose geometric and mass properties were:

W	=	15000 lbs	c	=	7.22 ft
I_{xx}	=	4947 slug/ft²	b	=	27.2 ft
I_{yy}	=	49332 "	S	=	185 ft²
I_{zz}	=	52764 "	(W/S)	=	81 lbs/ft²
I_{xz}	=	0 "	length	=	48 ft

The aerodynamics of the vehicle were linear with the exception that drag varied with α^2. The aircraft employed a single control surface and the lift due to the deflection of this surface was set to zero. The constant speed transfer function can, therefore, be expressed as:

$$\left(\frac{q}{\delta_e}\right) = \frac{M_{\delta_e}(s + 1/\tau_{\theta_2})}{s^2 + 2\zeta\,\omega_{sp}\, s + \omega_{sp}^2}$$

$$\left(\frac{\alpha}{\delta_e}\right) = \frac{M_{\delta_e}}{s^2 + 2\zeta\,\omega_{sp} s + \omega_{sp}^2}$$

$$\left(\frac{n_z}{\delta_{e_{cg}}}\right) = \frac{M_{\delta_e}(V_T/g)(1/\tau_{\theta_2})}{s^2 + 2\zeta\,\omega_{sp}\,s + \omega_{sp}^2}$$

The primary experiment matrix consisted of three short period frequency configurations at three values of (n/α). The points lie on lines of constant $\omega^2 n_{sp}/(n/\alpha)$, spanning the Level 1 and Level 2 boundaries of the MIL-F-8785 minimum short period frequency requirement.

The requisite short period frequencies were implemented by augmenting an unstable aerodynamic configuration through appropriate control system feedback gains of angle of attack $(\Delta\alpha)$ and pitch rate (q) (Figure B-1). It was not a program constraint to implement an unstable aerodynamics model; rather, the chosen methodology was advantageous for ease of configuration changes and simulation checkout.

The required variation in (n/α) was developed by changing the aerodynamics in the following manner:

- C_{L_α} was selected to achieve the desired (n/α):

$$(n/\alpha) = \frac{C_{L_\alpha}}{W}\,q\,S$$

- C_{L_o} was adjusted to maintain trim; i.e.,

$$C'_{L_o} = C_{L_o} + (C_{L_\alpha} - C'_{L_\alpha})\,\alpha_{TRIM}$$

- The drag terms, C_{D_o}, C_{D_α}, and $C_{D_{\alpha^2}}$ were adusted to maintain the same C_L/C_D relationship for each (n/α) configuration.

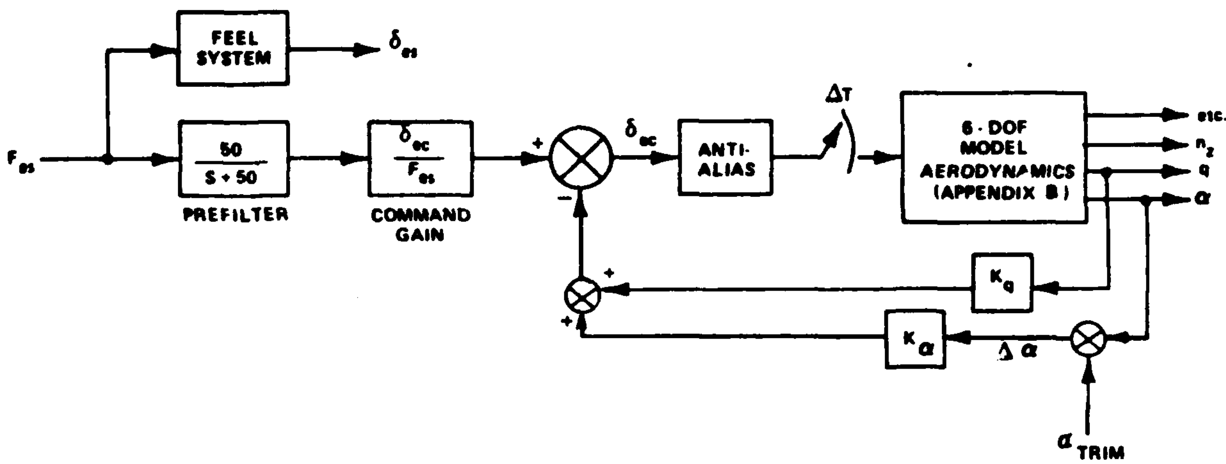


Figure B-1. MODEL SCHEMATIC DIAGRAM

The equations documenting this manipulation completely are contained in Reference 3. The net effect is to avoid any side effects on the experiment which would have occurred if the lift-curve slope (C_{L_α}) were changed without attendent changes in static lift and the drag equation. The complete aerodynamics package is presented in Table B-I (longitudinal) and Table B-II (lateral-directional).

Feedbacks around the lateral-directional model aerodynamics were not necessary except that a $\dot{\beta}$ feedback was used to augment dutch-roll damping. Otherwise, the lateral-directional aerodynamics were sufficient for good flying qualities and remained constant throughout the program.

The simulated model pilot location change was implemented by changing the distance of the pilot location relative to the model center of gravity (ℓ_p). This change affects the model translational acceleration equations and the model following transformations used in TIFS simulation (Appendix A).

Three-degree-of-freedom transfer functions are presented for the unaugmented model in Table B-III for the (n/α)=6, 20, and 70 g/rad model cases. The transfer functions are calculated at a flight condition of 218 KIAS and 12000 feet assuming standard day. The transfer function input was elevator deflection and the outputs are perturbation responses from trim.

Time histories of the model responses are presented in Appendix C for step pitch inputs. The time responses were taken prior to evaluation of each configuration.

Table B-I
LONGITUDINAL MODEL AERODYNAMICS

$$C_D = C_{D_0} + C_{D_\alpha}\alpha + C_{D_{\alpha^2}}\alpha^2 + C_{D_{\delta_e}}\delta_e$$

$$C_L = C_{L_0} + C_{L_\alpha}\alpha + C_{L_{\delta_e}}\delta_e$$

$$C_M = C_{M_0} + C_{M_\alpha}\alpha + C_{M_{\delta_e}}\delta_e + (C_{M_q}q + C_{M_{\dot\alpha}}\dot\alpha)\ c/2v$$

DERIVATIVE	VALUE	UNITS	REMARKS
C_{D_0}	*	-	* Varied in experiment [.0319, .04, .075]
C_{D_α}	*	deg^{-1}	* Varied in experiment [-.0012, -.0044, -.0202]
$C_{D_{\alpha^2}}$	*	deg^{-2}	* Varied in experiment [.0000, .0001, .0012]
$C_{D_{\delta_e}}$	0.000916	deg^{-1}	
C_{L_0}	*	-	* Varied in experiment [.3516, .02, -1.165]
C_{L_α}	*	deg^{-1}	* Varied in experiment [.0518, .1725, .604]
$C_{L_{\delta_e}}$	0.0	deg^{-1}	
C_{M_0}	-0.07642	-	
C_{M_α}	0.0328	deg^{-1}	
$C_{M_{\delta_e}}$	0.0237	deg^{-1}	
C_{M_q}	-0.73	deg^{-1}	
$C_{M_{\dot\alpha}}$	0.0	deg^{-1}	

Table B-II
LATERAL-DIRECTIONAL MODEL AERODYNAMICS

$$C_y = C_{y_\beta}\beta + C_{y_{\delta r}}\delta r + C_{y_{\delta a}}\delta a + (C_{y_p}p + C_{y_r}r)(\frac{b}{2V})$$

$$C_\ell = C_{\ell_\beta}\beta + C_{\ell_{\delta r}}\delta r + C_{\ell_{\delta a}}\delta a + (C_{\ell_p}p + C_{\ell_r}r)(\frac{b}{2V})$$

$$C_n = C_{n_\beta}\beta + C_{n_{\delta r}}\delta r + C_{n_{\delta a}}\delta a + (C_{n_p}p + C_{n_r}r)(\frac{b}{2V})$$

DERIVATIVE	VALUE	UNITS
C_{y_β}	-0.03	deg^{-1}
$C_{y_{\delta r}}$	0.00059	deg^{-1}
$C_{y_{\delta a}}$	0.0	deg^{-1}
C_{y_p}	0.0	-
C_{y_r}	0.0	-
C_{ℓ_β}	-0.00073	deg^{-1}
$C_{\ell_{\delta r}}$	0.0	deg^{-1}
$C_{\ell_{\delta a}}$	-0.00262	deg^{-1}
C_{ℓ_p}	-0.0069	deg^{-1}
C_{ℓ_r}	0.0058	deg^{-1}
C_{n_β}	0.007	deg^{-1}
$C_{n_{\delta r}}$	-0.00056	deg^{-1}
$C_{n_{\delta a}}$	0.0	deg^{-1}
C_{n_p}	-0.00017	deg^{-1}
C_{n_r}	-0.0551	deg^{-1}

Table B-III

THREE DEGREE-OF-FREEDOM, UNAUGMENTED MODEL TRANSFER FUNCTIONS

<u>(n/α) = 6 g/radian</u>

- characteristic equation:

$$447\ s^4 + 868.85\ s^3 - 3427.\ s^2 - 21.14\ s - 38.624$$

$$447(-1.970)[.042,\ .1059](3.905)\ *$$

- numerators:

$$\theta:\ -2695.5\ s^2 - 1198.8\ s - 37.58$$

$$-2695.5(.410)(.0339)$$

$$V:\ -1526.7\ s^3 - 2954.6\ s^2 - 233.17\ s + 37832.$$

$$-1526.7(-2.379)[.668,\ 3.227]$$

$$\alpha:\ -2695.0\ s^2 - 22.02\ s - 27.90$$

$$-2695.0[.040,\ .1018]$$

<u>(n/α) = 20 g/radian</u>

- characteristic equation:

$$447\ s^4 + 1318.9\ s^3 - 2746.6\ s^2 - 12.876\ s - 38.62$$

$$447(-1.420)[.047,\ .1181](4.359)$$

- numerators:

$$\theta:\ -2695.5\ s^2 - 3912.4\ s - 70.84$$

$$-2695.5(1.433)(.01834)$$

$$V:\ -1526.7\ s^3 - 4491.6\ s^2 - 34704.\ s + 125130.$$

$$-1526.7(-2.337)[.445,\ 5.921]$$

$$\alpha:\ -2695.0\ s^2 - 22.02\ s - 27.90$$

$$-2695.0[.040,\ .1018]$$

Table B-III (Cont'd)

THREE DEGREE-OF-FREEDOM, UNAUGMENTED MODEL TRANSFER FUNCTIONS

$(n/\alpha) = 70$ g/radian

- characteristic equation:

  $$447\ s^4 + 2927.7\ s^3 - 312.86\ s^2 - 20.19\ s - 38.62$$
  $$447(-.2621)[.349,\ .2226](6.656)$$

- numerators:

  $$\theta: \ -2695.5\ s^2 - 13614.\ s - 203.85$$
  $$-2695.5(5.036)(.0150)$$

  $$V: \ -1526.7\ s^3 - 9986.6\ s^2 - 201740.\ s + 437230.$$
  $$-1526.7(-1.929)[.347,\ 12.185]$$

  $$\alpha: \ -2695.0\ s^2 - 22.02\ s - 27.90$$
  $$-2695.0[.041,\ .1018]$$

* short hand notation: $(\zeta, \omega) \rightarrow s^2 + 2\ \zeta\omega s + \omega^2$

$(a) \rightarrow (s + a)$

Appendix C
CALIBRATION STEP TIME HISTORIES

Before each evaluation a calibration record was taken of the aircraft response to an automatically generated pitch step input. The step input was equivalent to 1.25 lbs pitch stick force.

A sampling of the calibration step records is presented in this appendix. The noise, shown on these flight records, is primarily from the data playback system. This noise did not, in any way, affect or contaminate the TIFS simulation.

The records show the model and TIFS responses in pitch rate, pitch acceleration, and normal acceleration at the evaluation cockpit. The model does not include any control surface actuators; therefore, the model responses do not exhibit any appreciable lag in the initial response to the pitch step. The delay in the response of the TIFS in following the "fast" model was accepted. The TIFS responses are used exclusively in the development of equivalent systems models (Section 6, Volume I); thus, the delay of the TIFS response is included. Also, note that the normal acceleration data are filtered accelerometer output. The responses include the structural modes of the host aircraft. Similarly, the $\dot{q}_{TIFS}$ parameter is derived by differencing the accelerometer outputs from the TIFS center of gravity and pilot station. Compensation of this signal was not attempted; therefore, $\dot{q}_{TIFS}$ is contaminated by the structural modes of the host aircraft.

The simulated pilot location was chosen to be representative of the aircraft classification and size. Therefore, the size of the initial n_z response "kick" may appear to be "small", but they are appropriate. The n_{z_p} response are, of course, a function of the simulated (n/α), ω_{sp}, and ℓ_p (among others) by the relationship that: $n_{z_p} = n_{z_{cg}} + \ell_p \dot{q}$

As shown in Volume I, the pilot location changes, although apparently "small" when viewed by the time history initial response, did affect flying qualities and may be better "viewed" in the frequency domain.

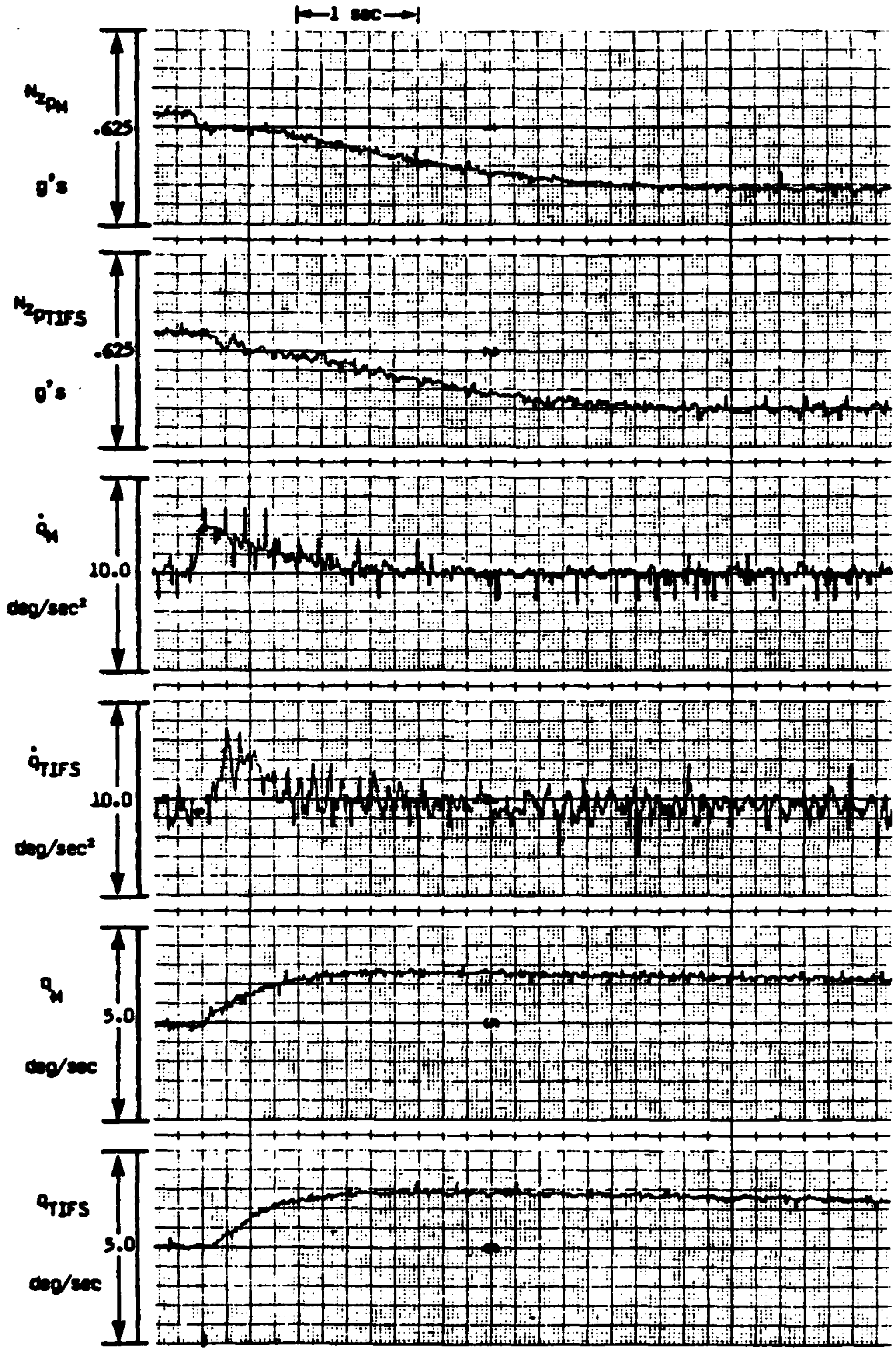


Figure C-2. CALIBRATION STEP TIME HISTORY: CONFIGURATION A2-2x, FLIGHT 802, RECORD NO. 14

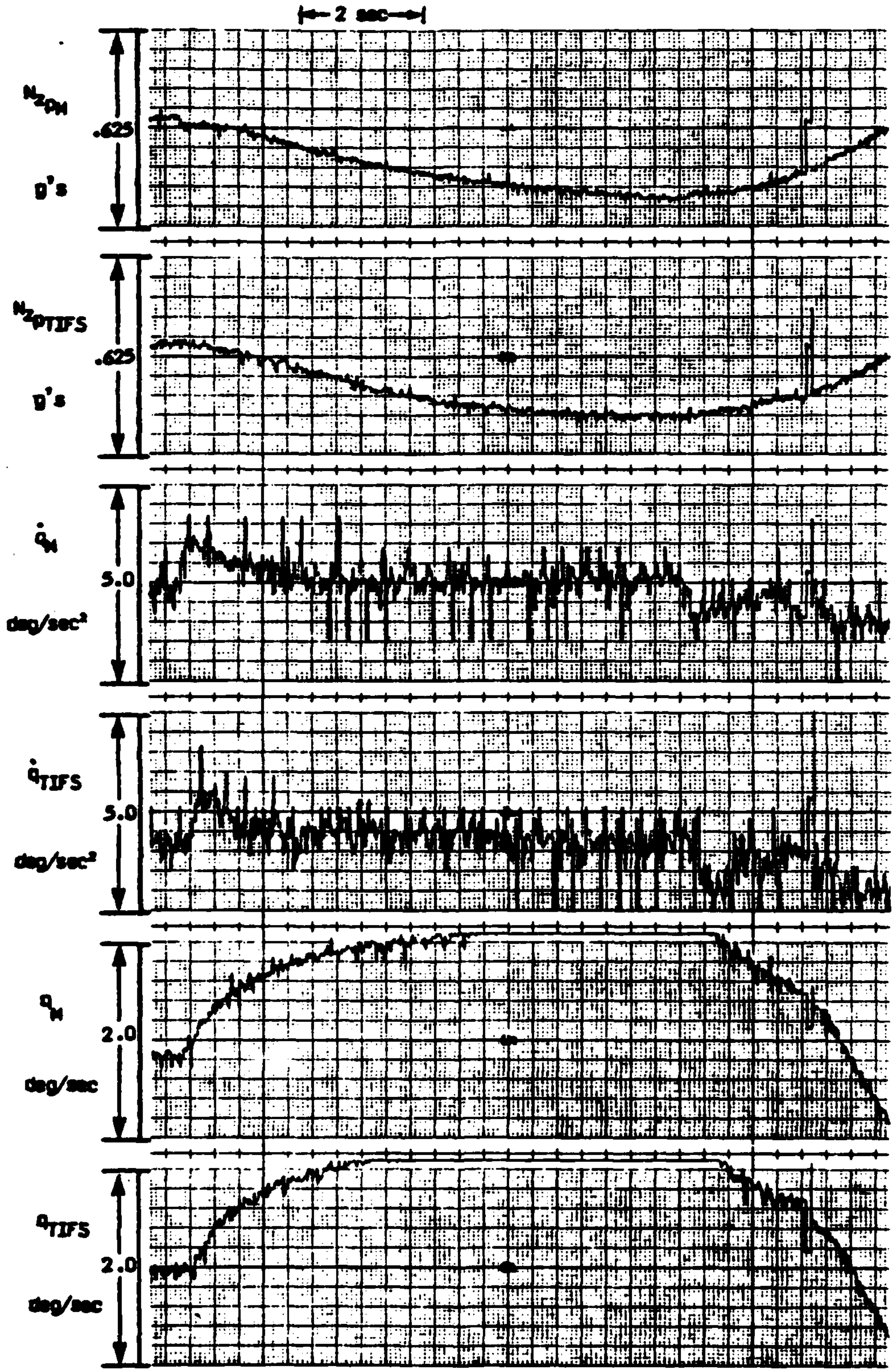


Figure C-3. CALIBRATION STEP TIME HISTORY: CONFIGURATION A3-3x, FLIGHT 803, RECORD NO. 16

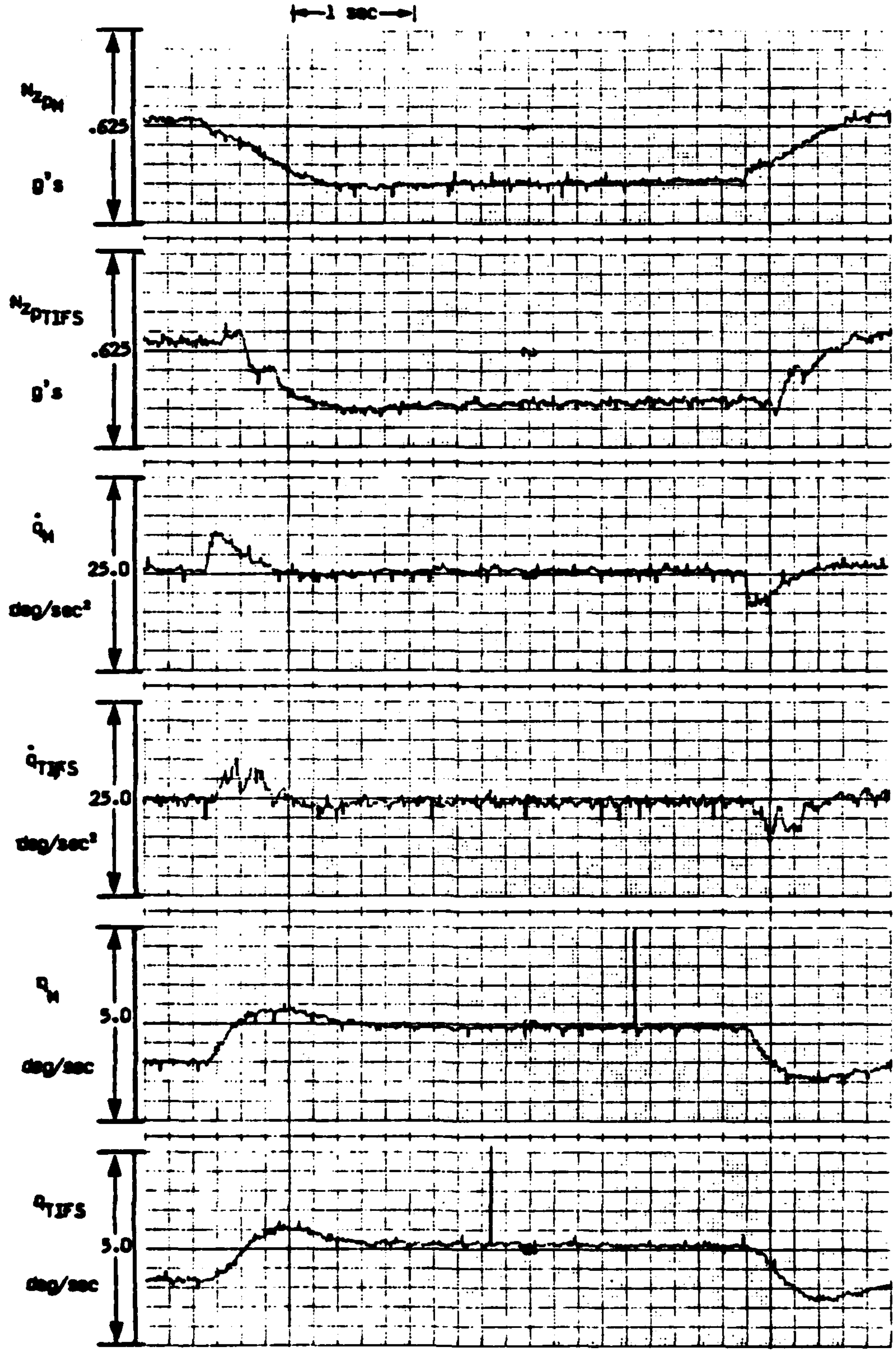


Figure C-4. CALIBRATION STEP TIME HISTORY: CONFIGURATION B1-1, FLIGHT 804, RECORD NO. 22

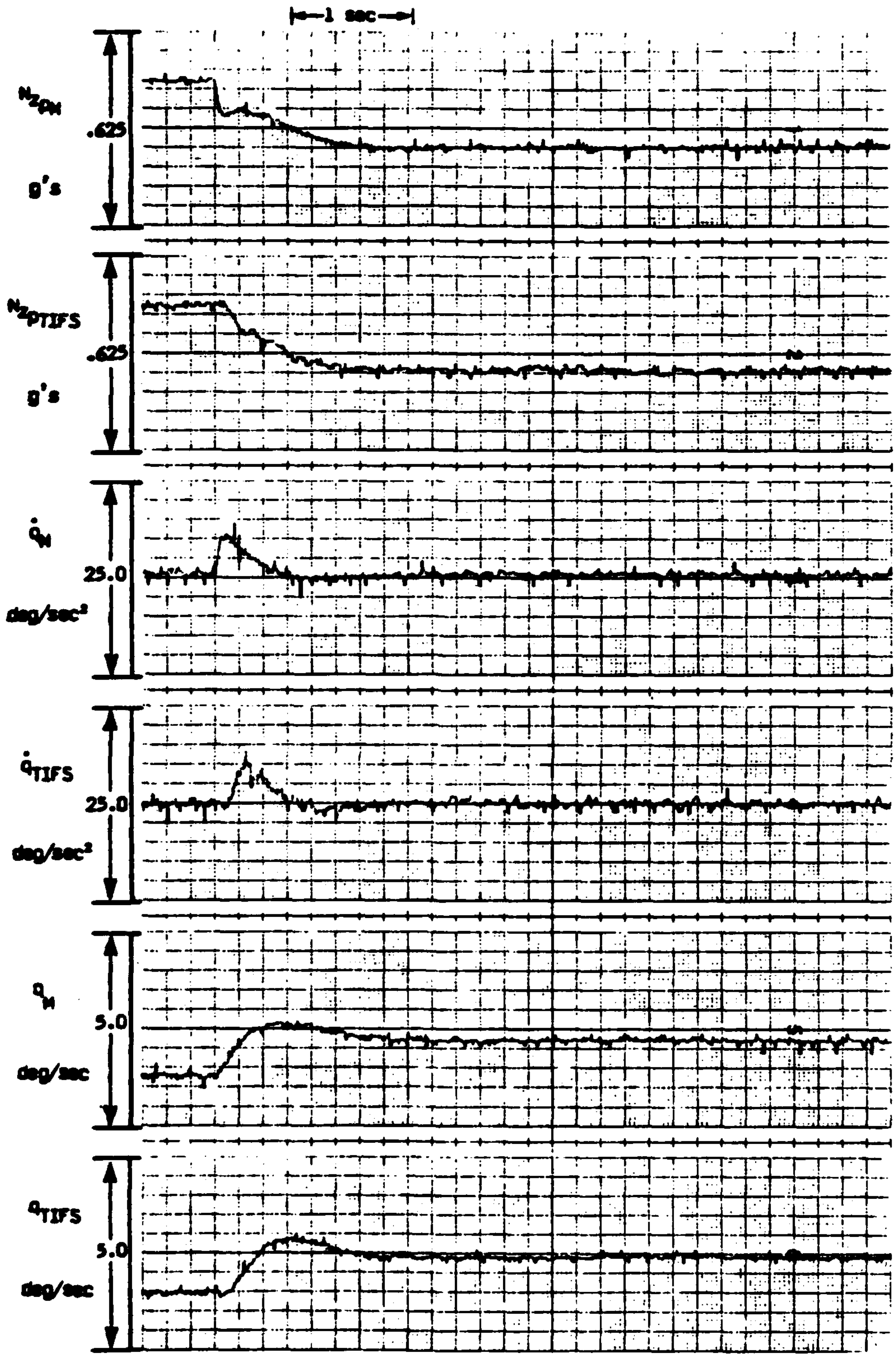


Figure C-5. CALIBRATION STEP TIME HISTORY: CONFIGURATION B1-1x, FLIGHT 806, RECORD NO. 09

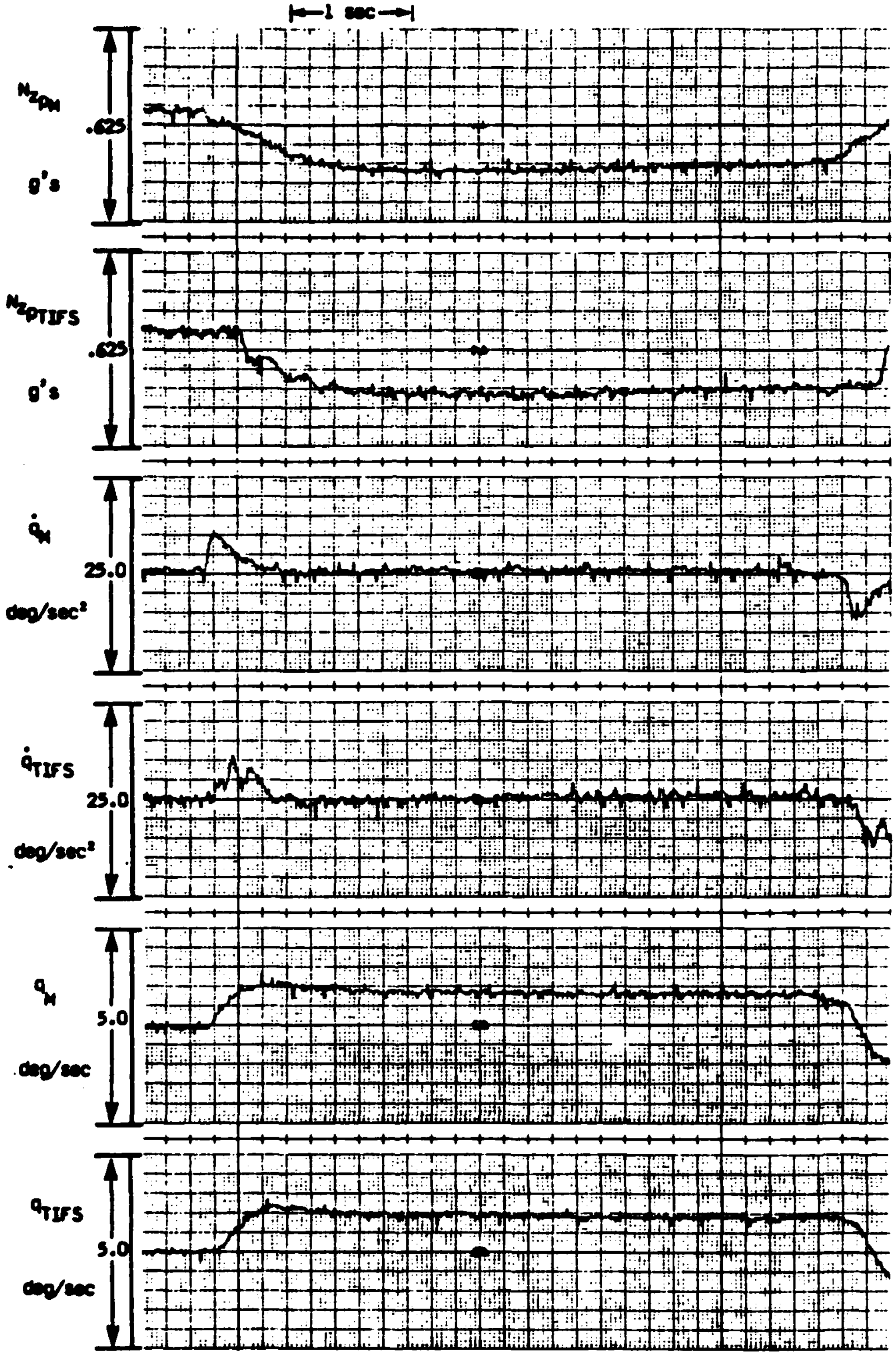


Figure C-6. CALIBRATION STEP TIME HISTORY: CONFIGURATION B1-2, FLIGHT 808, RECORD NO. 02

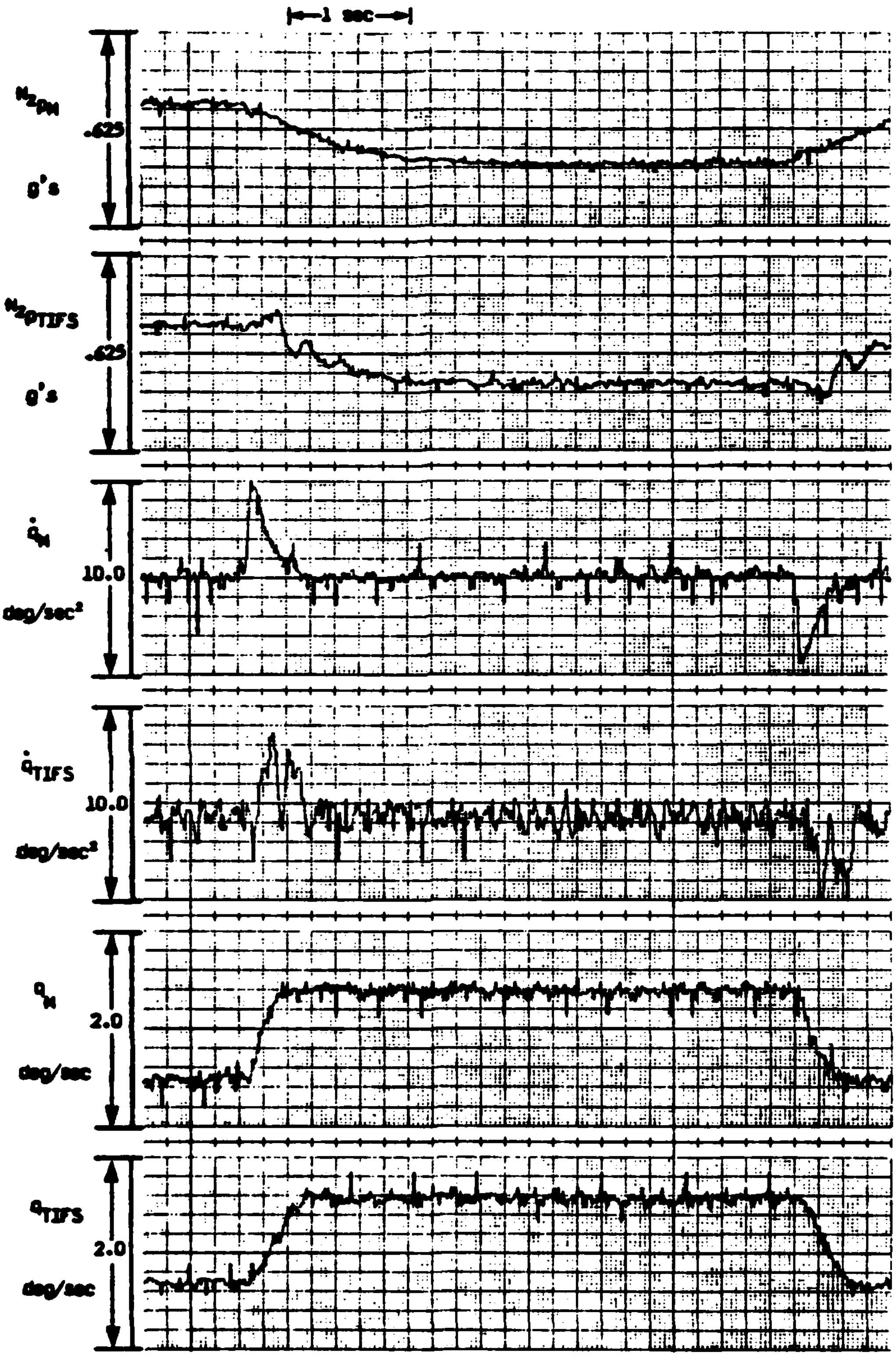


Figure C-7. CALIBRATION STEP TIME HISTORY: CONFIGURATION B1-3, FLIGHT 808, RECORD NO. 25

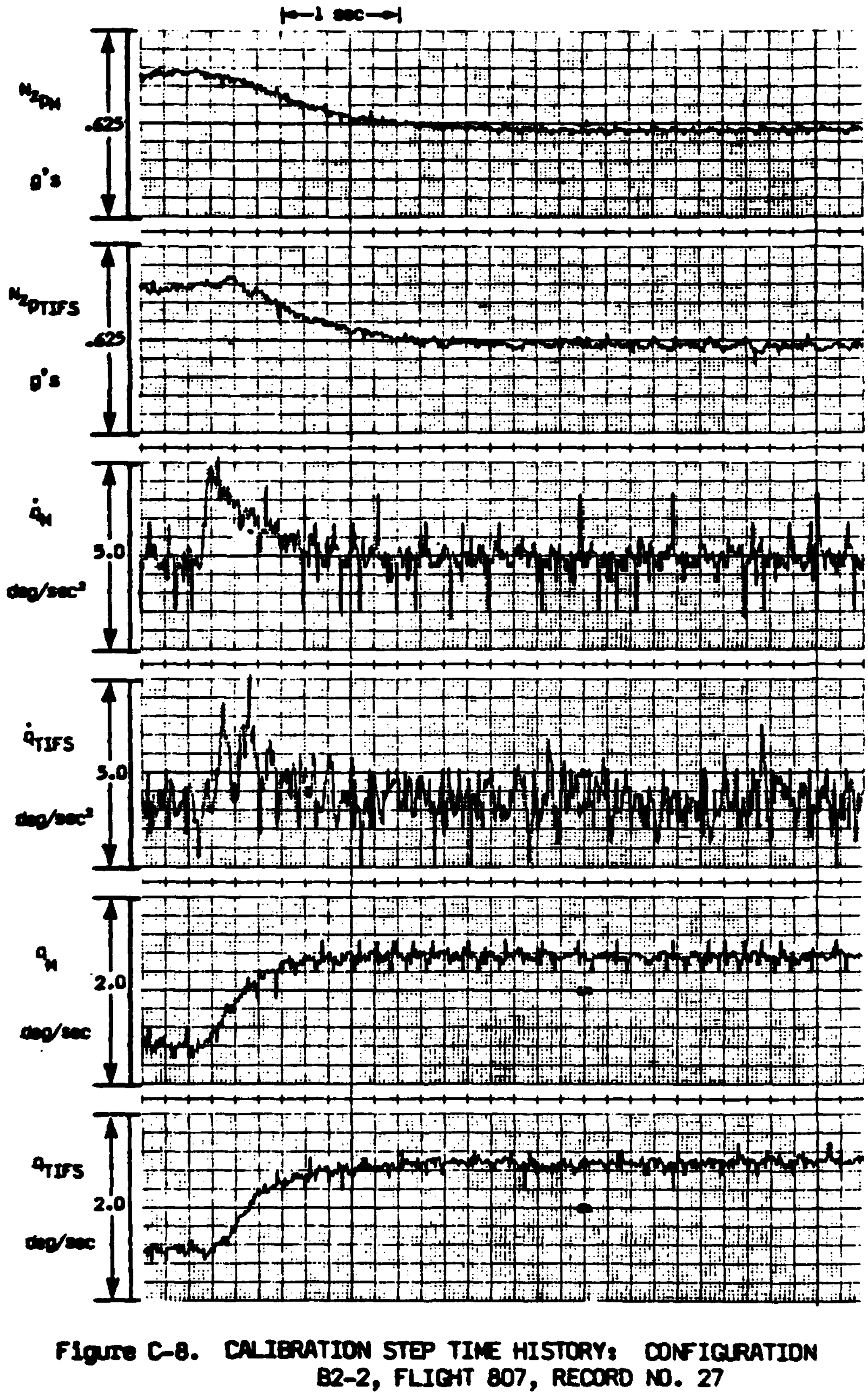


Figure C-8. CALIBRATION STEP TIME HISTORY: CONFIGURATION B2-2, FLIGHT 807, RECORD NO. 27

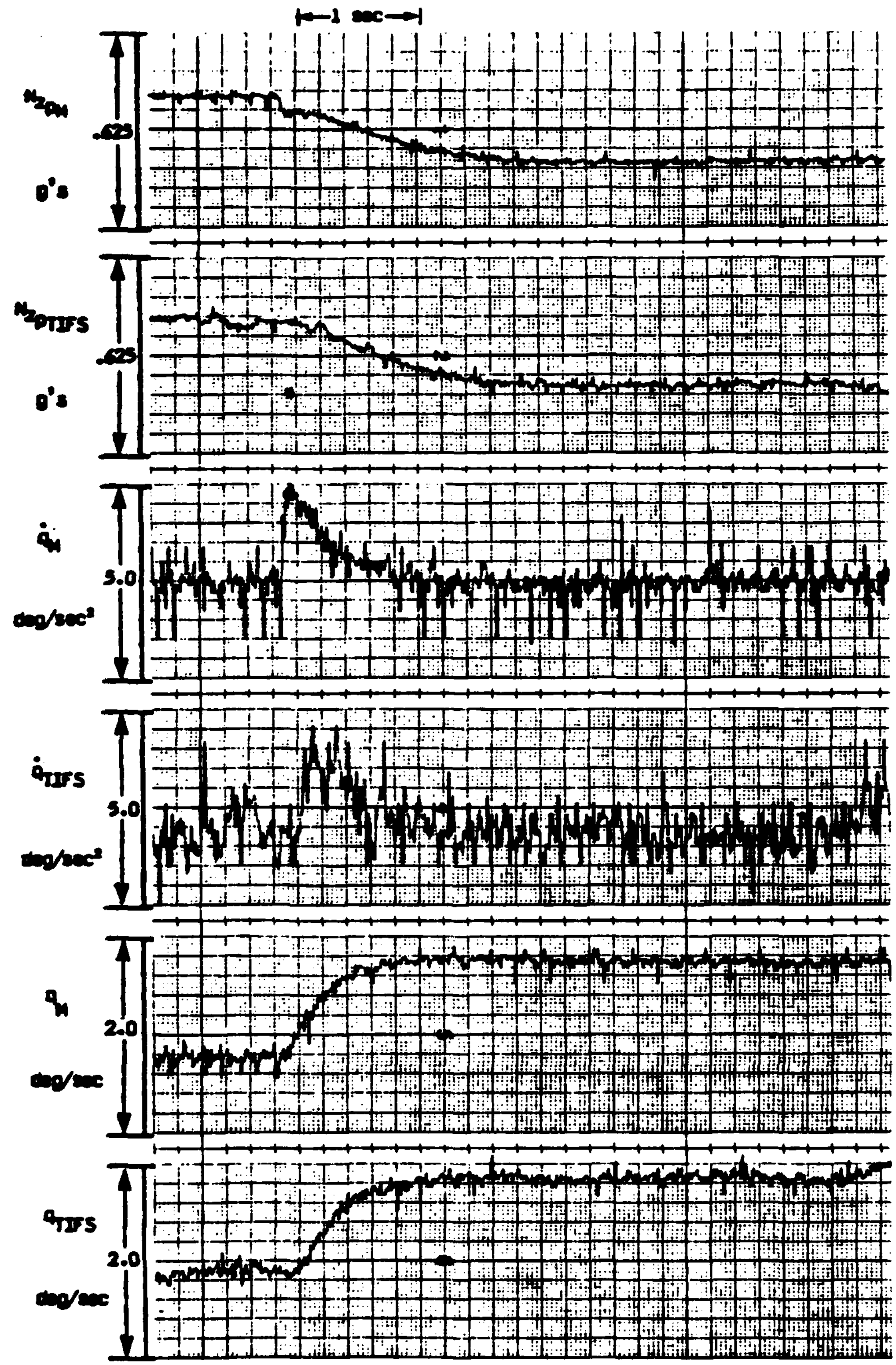


Figure C-9. CALIBRATION STEP TIME HISTORY: CONFIGURATION B2-2x, FLIGHT 808, RECORD NO. 08

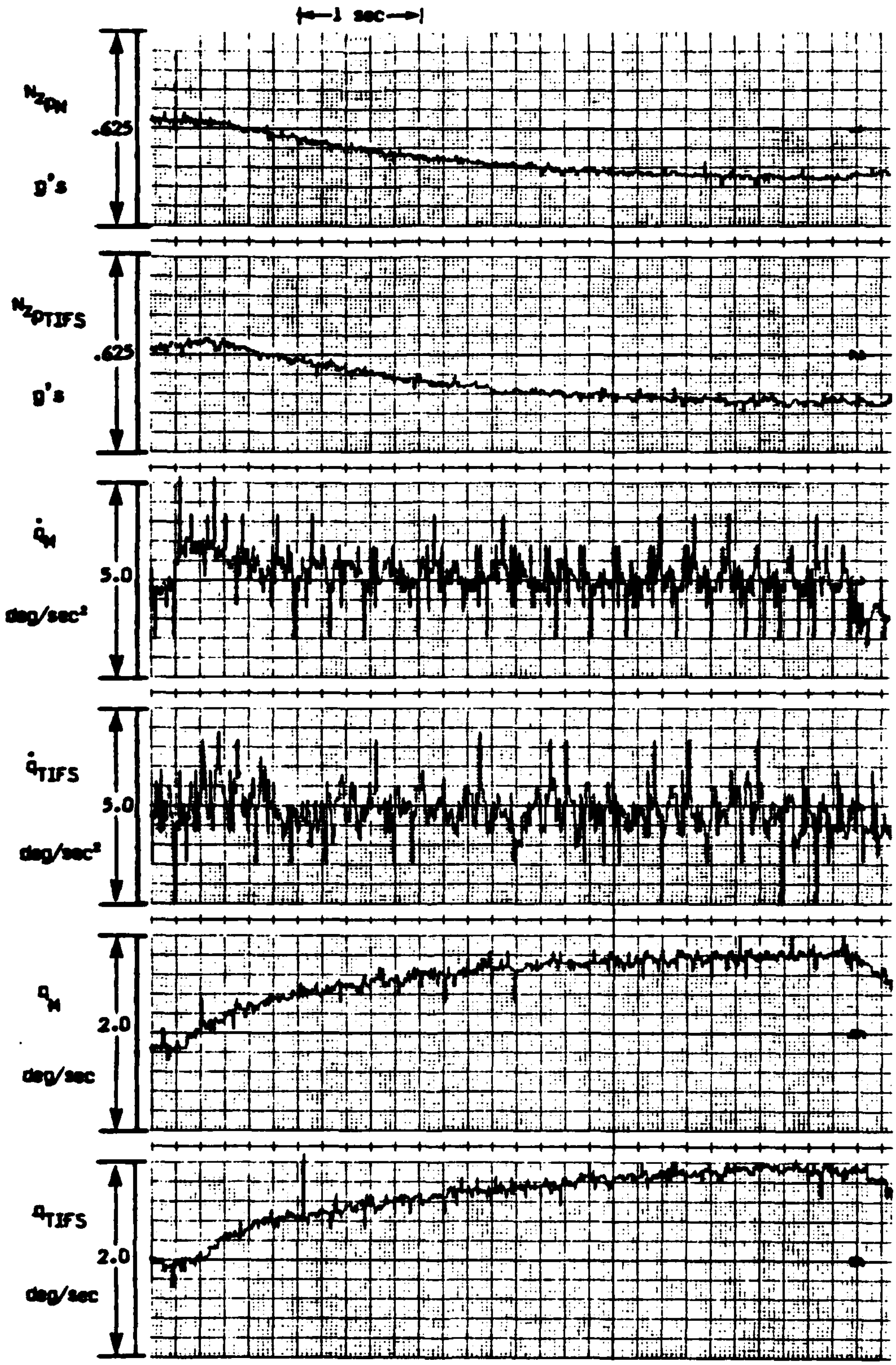


Figure C-10. CALIBRATION STEP TIME HISTORY: CONFIGURATION B3-3, FLIGHT 804, RECORD NO. 02

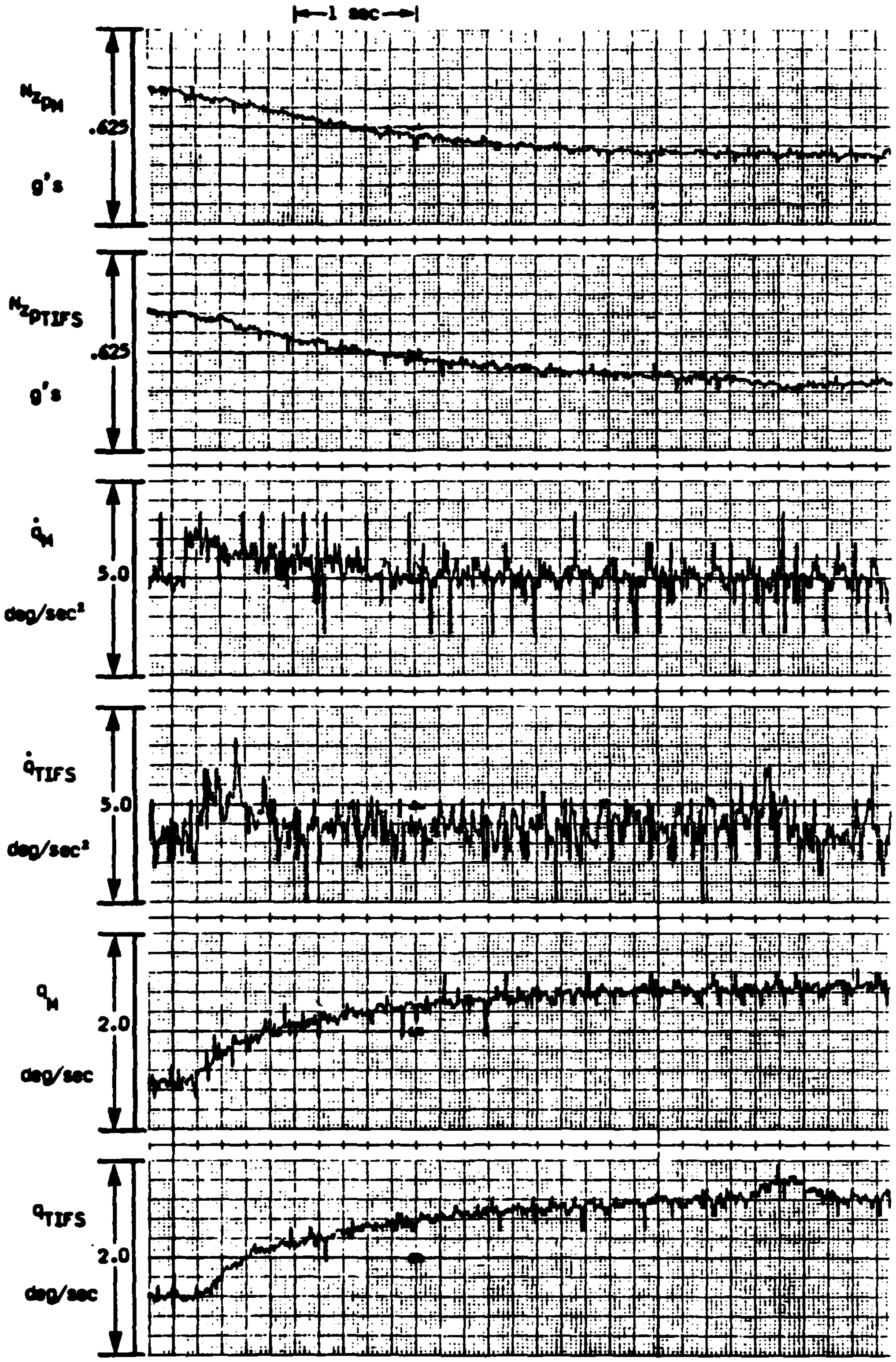


Figure C-11. CALIBRATION STEP TIME HISTORY: CONFIGURATION B3-3x, FLIGHT 806, RECORD NO. 24

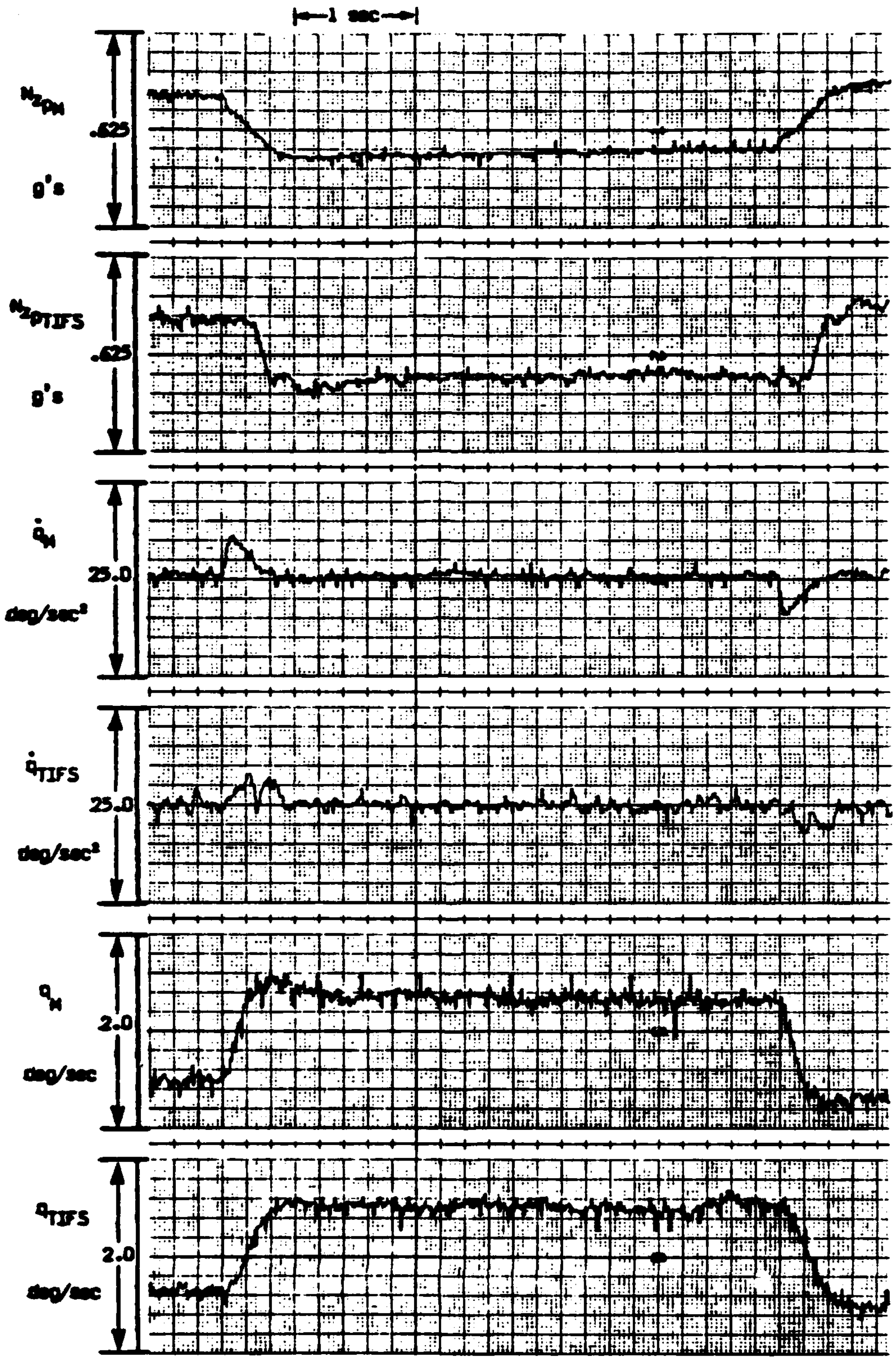


Figure C-12. CALIBRATION STEP TIME HISTORY: CONFIGURATION C1-1, FLIGHT 807, RECORD NO. 06

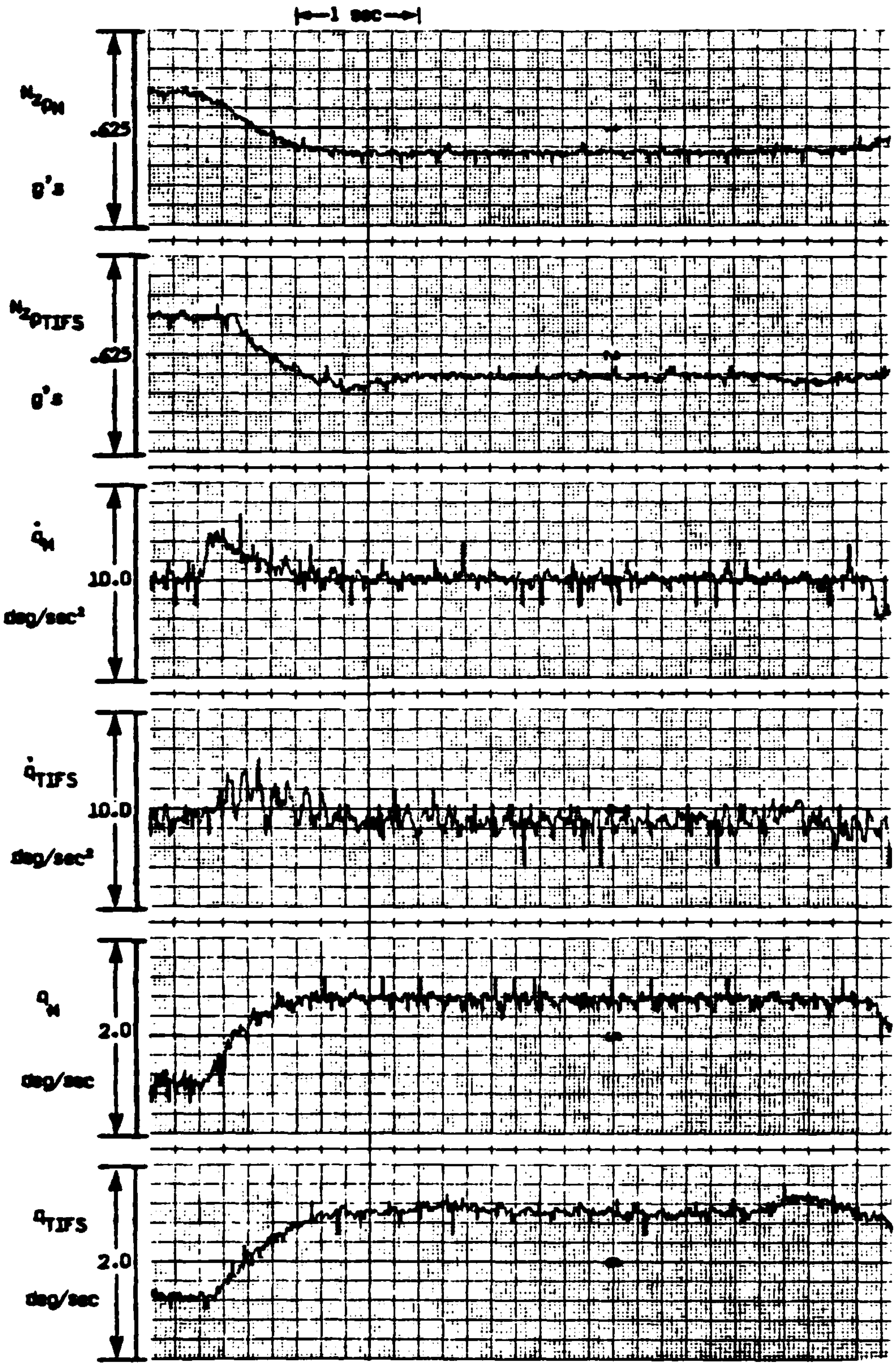


Figure C-13. CALIBRATION STEP TIME HISTORY: CONFIGURATION C2-2, FLIGHT 806, RECORD NO. 17

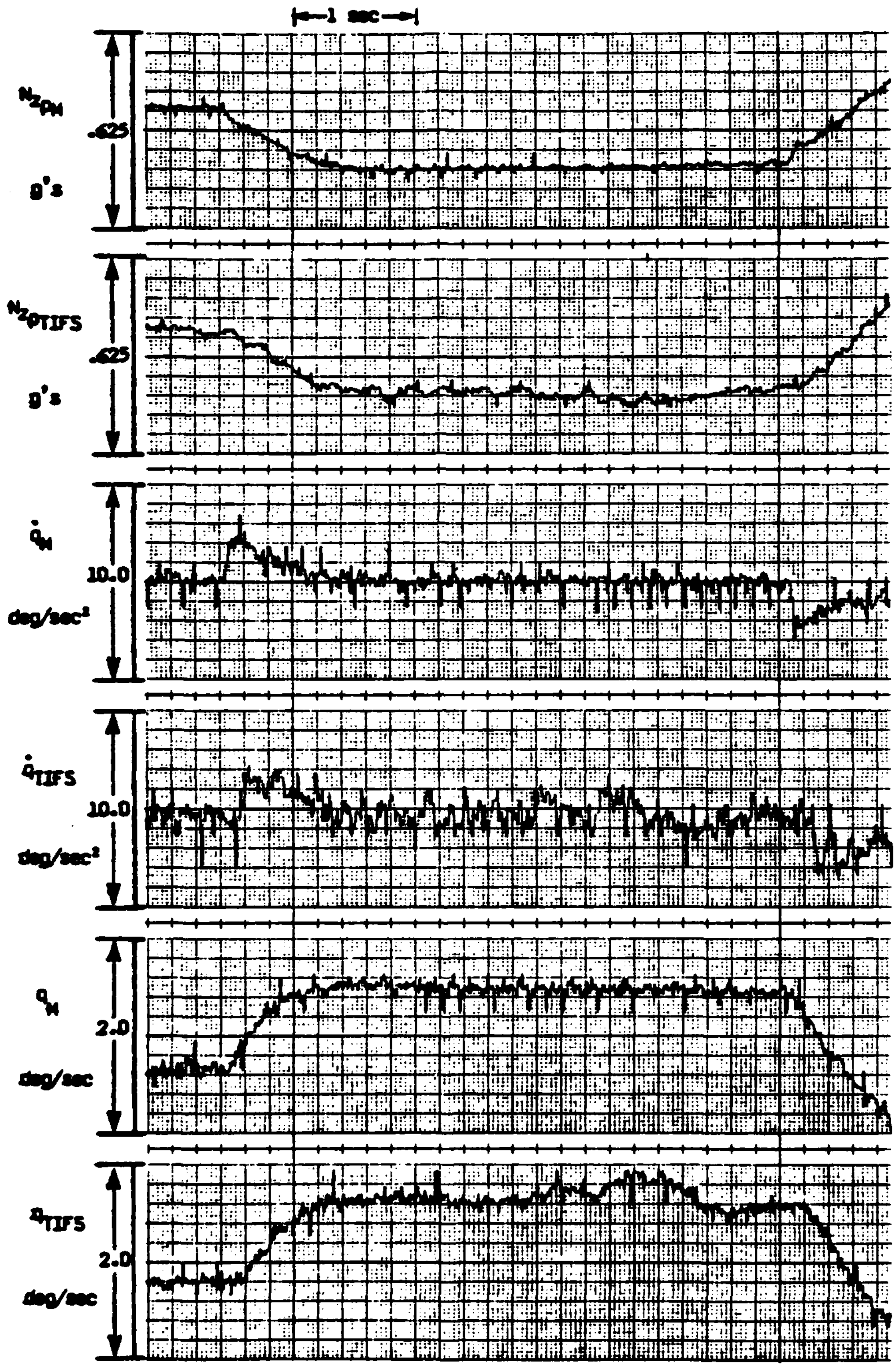


Figure C-14. CALIBRATION STEP TIME HISTORY: CONFIGURATION C2-2x, FLIGHT 805, RECORD NO. 01

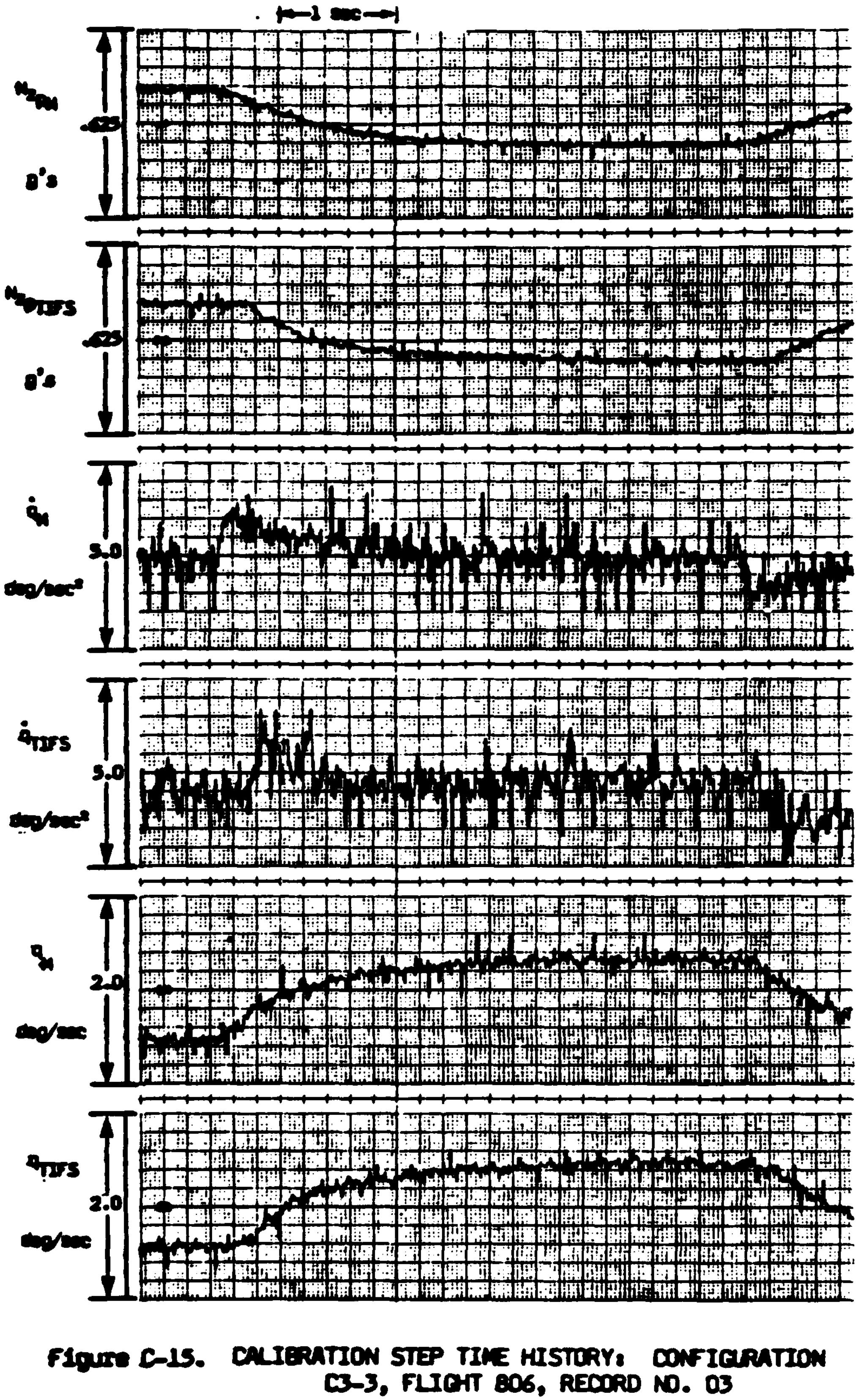


Figure C-15. CALIBRATION STEP TIME HISTORY: CONFIGURATION C3-3, FLIGHT 806, RECORD NO. 03

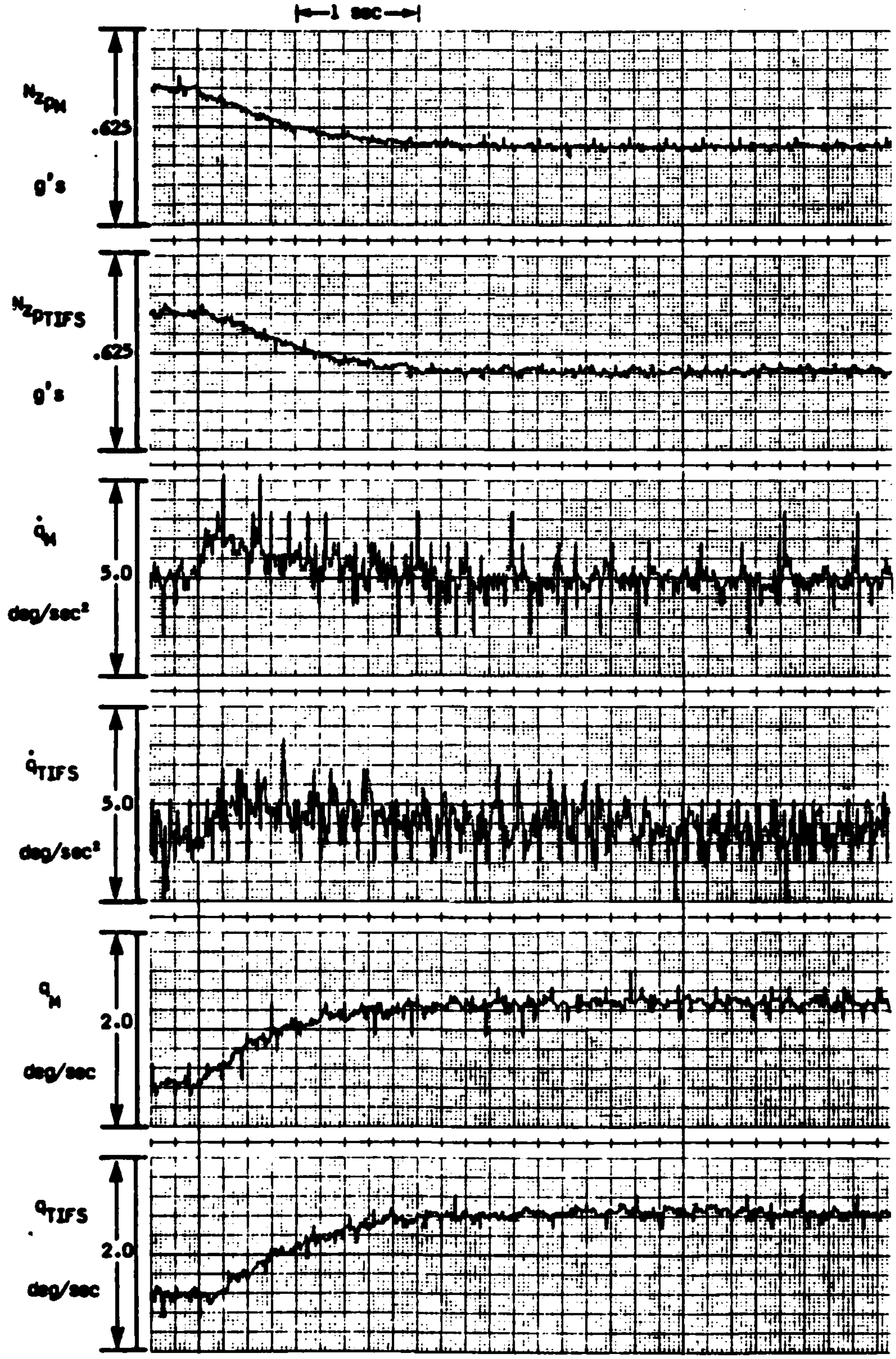


Figure C-16. CALIBRATION STEP TIME HISTORY: CONFIGURATION C3-3x, FLIGHT 807, RECORD NO. 17

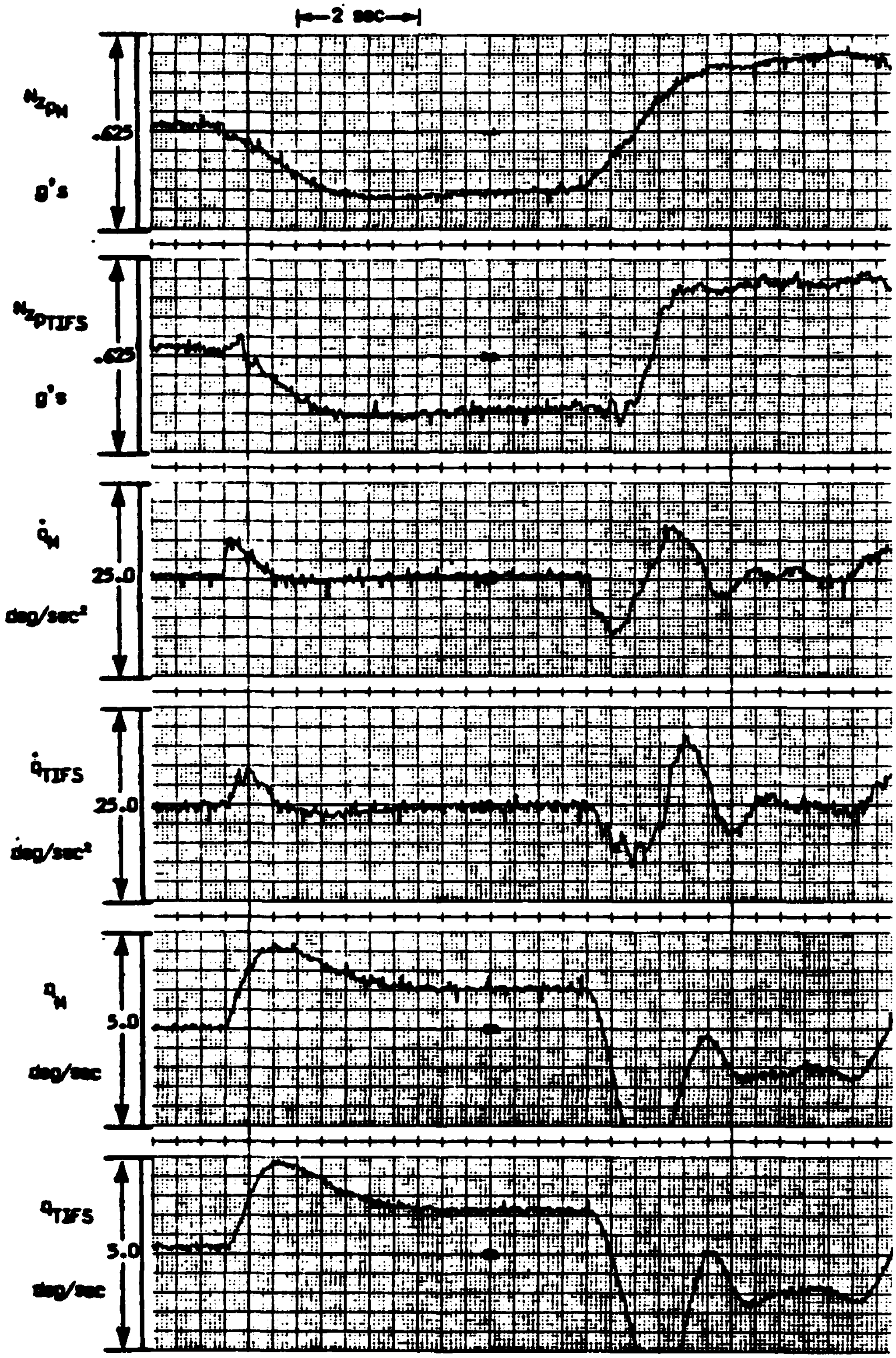


Figure C-1. CALIBRATION STEP TIME HISTORY: CONFIGURATION A1-1, FLIGHT 802, RECORD NO. 09

Appendix D
EQUIVALENT SYSTEM ANALYSIS

Selected records of flight data were translated into the frequency domain using a Fast Fourier Transformation (FFT) algorithm. 1024 points at a sample interval of .04 seconds were used. Primarily, tailored "frequency sweep" input records were analyzed since these records yield the best results. However, some task performance records were also analyzed to test for repeatability and nonlinearities.

Overall, the quality of the data and analysis results was good, particularly for the frequency sweep records. The normal acceleration transformations for the "A" series configurations, however, were poor. These data and attendant equivalent system results are, therefore, tentative.

The transfer function frequency response data were analyzed using an "Equivalent Systems" computer program. This computer program is identical to the program developed at McAir (Reference 4). This exercise provided:

- Data for checking compliance with the military specifications where equivalent system models are permitted.

- Frequency domain low order transfer function models of the actual TIFS responses to evaluation pilot inputs.

- "Least-squares" curve fit to the frequency response data for subsequent frequency domain analyses, such as the bandwidth and Neal-Smith criteria. (The actual Bode plots could have been used, but the noise characteristics essentially rendered these responses useless for these applications.

(Flight records of Configuration B2-2 and B2-3 were not available.)

The frequency data and equivalent system results include the sensor dynamics and signal conditioning filters for each signal. From Appendix A, approximately 17 milliseconds of delay is accountable to pitch rate gyro dynamics and filters. About 27 msec is attributable to the normal accelerometer dynamics and filters. These delay values are subtracted from the equivalent systems matches of the flight data to derive the actual "equivalent" responses of the aircraft to pilot input.

Equivalent system models were developed for each configuration pitch rate and normal acceleration responses (at the evaluation cockpit) to pitch stick force (F_{es}). (Normal acceleration at the simulated aircraft center of rotation or center of gravity were not available.) The following list indicates the low order model and the table in which the results are compiled:

- Table D-I: pitch rate match only, τ_{θ_2} fixed. Low order model:

$$\left(\frac{q}{F_{es}}\right) = \frac{K_q\,(\tau_{\theta_2} s + 1)\, e^{-\tau_{q_e} s}}{(s/\omega_{sp_e})^2 + (2\zeta/\omega_{sp_e})s + 1}$$

- Table D-II: pitch rate match only, τ_{θ_2} free. Low order model: same as Table D-I.

- Table D-III: normal acceleration match only, 0/2nd model. Low order model:

$$\left(\frac{N_{z_p}}{F_{es}}\right) = \frac{K_{n_{z_e}}\, e^{-\tau_{n_{z_e}} s}}{(s/\omega_{sp_e})^2 + (2\zeta/\omega_{sp_e})s + 1}$$

- Table D-IV: normal acceleration match only, 2/2nd model. Low order model:

$$\left(\frac{N_{z_p}}{F_{es}}\right) = \frac{K_{n_{z_e}}\left[\left(\frac{s}{\omega_n}\right)^2 + \left(\frac{2\zeta}{\omega_n}\right) s + 1\right] e^{-\tau_{n_{z_e}} s}}{(s/\omega_{sp_e})^2 + (2\zeta/\omega_{sp_e})s + 1}$$

- Table D-V: Simultaneous pitch rate and normal acceleration match, τ_{θ_2} free. Low order models listed under Tables D-I and D-III.

All matches spanned the frequency range of .2 to 10. radians per second. The cost fuction for each match was:

$$\text{cost} = \sum_{i=1}^{NPTS} \left[(\Delta G_i)^2 + W\,(\Delta P_i)^2 \right]$$

where $\Delta G_i = \text{Gain}_{HOS} - \text{Gain}_{LOS}$ [dB]

$\Delta P_i = \text{Phase}_{HOS} - \text{Phase}_{LOS}$ [degrees]

NPTS = Number of Points

The standard phase weighting value (W) of .02 was used. The cost functions were normalized by the number of points for the matches. Frequency weighted cost functions were not used.

In Figures D-1 through D-18, the pitch rate only, equivalent system matches to the FFT data are shown. The pitch rate numerator time constant, τ_{θ_2} was free in the match. These plots correspond to the results of Table D-II.

In Figures D-19 through D-36, the normal acceleration equivalent system matches are shown. The low order model was a second-over-second order model corresponding to the results of Table D-IV.

On each figure, the raw FFT data points are drawn by the solid line and the low order equivalent system model is represented by the (*) symbol. The plots of Figures D-1 through D-36 represent the transfer function frequency responses, but also include the sensor and signal conditioning dynamics and a scale factor of .1 on the stick force signal. The tables (D-I through D-V) have been compensated for these factors.

It was of interest in this program to derive a quantitative measure of the configuration $(\dot{h}_p/\theta)$ frequency responses (Section 6). The available data were the pitch rate and normal acceleration at the evaluation pilot station responses. It is approximately the case that:

(1) $n_{z_{cg}} \approx (V/g)\,\dot{\gamma}$

(2) $\dot{h}_{cg} \approx V\,\gamma$

(3) $q \approx \dot{\theta}$

then define:

(4) $\dot{h}_p = \dot{h}_{cg} + \ell_p(q)$

and (5) $(\dot{h}_p/\theta) = V(1 - \alpha/\theta) + \ell_p(s)$

Equation (5) equals:

$$\left(\frac{\dot{h}_p}{\theta}\right) = \frac{\left[\left(\frac{V(L_{\delta_e})}{M_{\delta_e} - M_{\dot{\alpha}}L_{\delta_e}}\right) + \ell_p\right]s^2 + \left[V\,\frac{(-M_{\delta_e} - L_{\delta_e}M_q)}{(M_{\delta_e} - M_{\dot{\alpha}}\,L_{\delta_e})} + \ell_p(1/\tau_{\theta_2}) + V\right]s + V\,(1/\tau_{\theta_2})}{(s + 1/\tau_{\theta_2})}$$

where $(1/\tau_{\theta_2}) = \left(\frac{M_{\delta_e}L_\alpha - M_\alpha L_{\delta_e}}{M_{\delta_e} - M_{\dot{\alpha}}L_{\delta_e}}\right)$

for $L_{\delta_e} = 0$ and $\ell_p \neq 0$, Equation (5) becomes

(6) $$\left(\frac{\dot{h}_p}{\theta}\right) = \frac{\ell_p s^2 + \ell_p(1/\tau_{\theta_2})\,s + V(1/\tau_{\theta_2})}{(s + 1/\tau_{\theta_2})}$$

from the data available for this program:

$$\frac{(n_{z_p}/F_{es})}{(q/F_{es})} = \frac{n_{z_{cg}} + \ell_p(\dot{q})}{q}$$

$$= \frac{(V/g)\,\dot{\gamma} + \ell_p\dot{q}}{q} \qquad \text{using Equation (1)}$$

$$\simeq \frac{(V/g)\,\gamma + \ell_p q}{\theta}$$

$$\simeq \frac{\dot{h}_{cg} + \ell_p(q)}{\theta} \qquad \text{using Equation (2)}$$

$$(7) \qquad \frac{(n_{z_p}/F_{es})}{(q/F_{es})} \simeq \left(\frac{\dot{h}_p}{\theta}\right)$$

The relationship between normal acceleration and pitch rate is provided by Equation (7). These data were used to generate the ($\dot{h}_p/\theta$) frequency responses. The n_{z_p} and q transfer function data were taken from the previous equivalent system matches (Tables D-IV and D-II, respectively). These models were used as best approximations to the frequency response data. The raw data were unsuitable for this analysis because of noise.

An "effective" pilot location was approximated using Equation (7) as the high order system and fitting these data with the low order system of Equation (6). Effective pilot location was derived for each configuration in using this method. The low order model was of the form of Equation (6). Airspeed (v) was constant. The "free" low order parameters were ($1/\tau_{\theta_2}$) and ℓ_p. The match was performed over a frequency range of .1 to 10. rad/sec. Thiry-one points, equally spaced logarithmetically, were employed.

The results of this exercise are compiled as Table D-VI. The plots corresponding to Table D-VI are presented as Figures D-37 through D-51. Note in Table D-VI that the suspect data for the "A" series configurations yield extremely high cost functions. These results should be used cautiously.

Several equivalent model forms were used in the analysis of the flight data. The equivalent model parameters were then compared to the MIL-F-8785C short period frequency, short period damping ratio, and time delay requirements. This correlation is presented in Figures D-52 through D-63.

Table D-I
PITCH RATE MATCHING ONLY - τ_{θ_2} FIXED

CONFIG	FLIGHT/ RECORD NO.	K_{q_e} ($\times10^{-1}$)	ζ_{SP_e}	ω_{SP_e} (rad/sec)	$\tau_{\theta_{2e}}$ ** (sec)	τ_{q_e} (sec)	COST/ NPTS	NPTS
A1-1	F802 R09	5.84	.44	1.67	2.315	.108	31.0	46
A2-2x	F802 R19*	7.31	.79	1.17	2.315	.153	12.5	45
A3-3x	F803 R19	9.45	1.33	0.73	2.315	.155	6.7	41
B1-1	F805 R14	5.18	.47	3.19	.694	.082	4.7	43
B1-1x	F806 R16	6.31	.57	3.25	.694	.115	4.2	41
B1-2	F808 R07	5.66	.64	3.04	.694	.076	4.5	48
B1-3	F808 R27*	7.98	1.28	2.54	.694	.079	9.1	45
B2-2x	F808 R12	8.19	.97	2.08	.694	.126	16.6	42
B3-3	F804 R09	7.04	1.03	1.46	.694	.090	1.8	43
B3-3x	F806 R29	5.76	1.05	1.67	.694	.131	2.8	48
C1-1	F808 R18	6.68	.67	5.07	.198	.061	18.0	48
C2-2	F806 R23	7.51	.83	3.01	.198	.067	2.5	44
C2-2x	F808 R24	6.92	.80	3.56	.198	.105	2.2	41
C3-3	F804 R32	6.69	.86	2.12	.198	.063	3.0	39
C3-3x	F808 R37	7.13	1.01	2.41	.198	.108	4.2	46
Other records:								
C1-1	F808 R17*	7.29	.80	4.89	.198	.047	5.9	43
C3-3	F806 R08	6.69	.86	2.12	.198	.045	2.0	39

- Frequency range .1 to 10. rps

** "Fixed" in matching process

* Task Record

Table D-II
PITCH RATE MATCHING ONLY - τ_{θ_2} FREE

CONFIG	FLIGHT/ RECORD NO.	K_{q_e} ($\times 10^{-1}$)	ζ_{SP_e}	ω_{SP_e} (rad/sec)	$\tau_{\theta 2_e}$ (sec)	τ_{q_e} (sec)	COST/ NPTS	NPTS
A1-1	F802 R09	6.63	.42	1.75	1.762	.105	31.0	46
A2-2x	F802 R19*	9.70	.65	1.75	0.727	.143	12.1	45
A3-3x	F803 R19	9.19	1.22	0.87	1.687	.155	6.7	41
B1-1	F805 R14	7.44	.35	4.10	.190	.039	3.0	43
B1-1x	F806 R16	8.10	.43	4.00	.272	.087	3.3	41
B1-2	F808 R07	6.83	.49	3.91	.272	.053	4.2	48
B1-3	F808 R27*	8.30	2.04	1.21	2.790	.075	9.1	45
B2-2x	F808 R12	8.48	.96	5.27	.0001	.039	15.8	42
B3-3	F804 R09	7.01	1.03	1.48	.673	.090	1.8	43
B3-3x	F806 R29	5.50	1.11	1.20	1.381	.128	2.8	48
C1-1	F808 R18	7.09	.59	6.64	.0001	-.024	17.7	48
C2-2	F806 R23	7.34	.79	2.75	.256	.071	2.5	44
C2-2x	F808 R24	7.29	.93	5.24	.0001	.034	2.0	41
C3-3	F804 R32	7.34	1.13	2.87	.0001	-.020	2.5	39
C3-3x	F808 R37	7.46	1.43	3.77	.0001	.041	4.0	46
<u>Other records</u>:								
A2-2x	F802 R20	8.83	.71	1.12	1.812	.105	43.0	45
C1-1	F808 R18**	7.31	.60	6.76	.0001	-.017	0.9	48
C1-1	F808 R17*	7.52	.78	7.26	.0001	-.021	5.7	43
C3-3	F806 R08	6.90	.96	2.36	.1358	.036	2.0	39

• Frequency range .1 to 10. rps except ** .70 to 11.0 rps

* Task Record

Table D-III
NORMAL ACCELERATION AT PILOT STATION MATCHING ONLY; 0/2 ORDER LOS

CONFIG	FLIGHT/ RECORD NO.	$K_{n_{z_e}}$ ($X10^{-1}$)	ζ_{SP_e}	ω_{SP_e} (rad/sec)	$\tau_{n_{z_e}}$ (sec)	COST/ NPTS	NPTS
A1-1	F802 R09	3.52	.61	2.01	.141	80[1]	46
A2-2x	F802 R19*	3.58	(3.885)	(.004)[2]	-.078	221[1]	45
A3-3x	F803 R19	4.74	(10.22)	(.001)[2]	.063	78[1]	41
B1-1	F805 R14	1.94	.83	4.68	.132	17.2	43
B1-1x	F806 R16	2.19	.91	2.64	-.180	25.8	41
B1-2	F808 R07	1.57	1.05	5.06	.118	7.0	48
B1-3	F808 R27*	1.95	(.560)	(.011)[2]	.185	12.2	45
B2-2x	F808 R12	1.67	1.04	2.20	-.159	20.6	42
B3-3	F804 R09	1.81	1.34	2.08	.097	3.9	43
B3-3x	F806 R29	1.48	1.06	1.56	-.160	11.7	48
C1-1	F808 R18	1.50	.48	6.69	.088	13.6	48
C2-2	F806 R23	1.76	1.10	5.86	.136	2.0	44
C2-2x	F808 R24	1.51	.66	3.65	-.047	2.6	41
C3-3	F804 R32	1.62	1.34	3.59	.114	2.5	39
C3-3x	F808 R37	1.49	.93	2.83	-.018	7.8	46
Other records:							
A2-2x	F802 R20	2.13	(1.28)	(.022)[2]	.588	89.0[1]	45
C1-1	F808 R17*	1.77	.62	7.12	.085	5.2	43
C3-3	F806 R08	1.55	1.14	3.29	.095	1.2	39

* Task Record

● Frequency range .1 to 10. rps unless noted otherwise

(1) Extremely poor data quality; see text

(2) Two real roots, (a)(b): (as + 1)(bs + 1)

Table D-IV

NORMAL ACCELERATION AT PILOT STATION MATCHING ONLY; 2/2 ORDER LOS

CONFIG	FLIGHT/ RECORD NO.	$K_{n_{z_e}}$ (x10-1)	ζ_N or (a) (2)	ω_N or (b) (2)	ζ_{SP_e}	ω_{SP} (rad/sec)	$\tau_{n_{z_e}}$ (sec)	COST/ NPTS	NPTS
A1-1	F802 R09	2.91	.25	5.12	.50	2.50	.457	64.7(1)	46
A2-2x	F802 R19*	2.36	(.317)	(.012)(2)	(4.11)	(.033)(2)	-.094	210.(1)	45
A3-3x	F803 R19	4.36	1.03	11.25	(11.19)	(.005)	.089	71.(1)	41
B1-1	F805 R14	1.66	.86	7.75	.60	3.47	.275	2.4	43
B1-1x	F806 R16	1.51	.12	5.93	.59	4.13	.126	6.9	41
B1-2	F808 R07	1.24	(.541)	(.003)	.66	2.22	.188	5.3	48
B1-3	F808 R27*	1.90	.55	6.60	(.588)	(.008)	.410	8.2	45
B2-2x	F808 R12	1.22	.41	4.89	.54	2.08	.087	8.9	42
B3-3	F804 R09	1.67	(.113)	(.061)	1.03	1.70	.221	3.6	43
B3-3x	F806 R29	1.17	.68	6.33	.72	1.44	.048	7.6	48
C1-1	F808 R18	1.07	(.769)	(.008)	.86	3.64	.209	11.9	48
C2-2	F806 R23	1.66	(.149)	(.002)	.85	3.94	.192	1.4	44
C2-2x	F808 R24	1.55	.36	10.73	.73	4.43	.093	2.4	41
C3-3	F804 R32	1.56	(.107)	(.010)	1.08	2.87	.178	2.3	39
C3-3x	F808 R37	1.46	.38	9.30	1.08	3.66	.158	7.5	46
Other records:									
A2-2x	F802 R20	2.17	(.138)	(.004)	(1.44)	(.086)	.646	89.0(1)	45
C1-1	F808 R17*	1.59	(.253)	(.018)	.67	4.71	.177	4.6	43
C1-1	F808 R18**	1.49	(.266)	(.023)	.66	4.83	.202	1.2	48
C3-3	F806 R08	1.48	(.120)	(.006)	.94	2.71	.164	1.1	39

* Task Record

● Frequency range .1 to 10. rps except ** .7 to 11. rps

(1) Extremely poor data quality; see text

(2) Two real roots, (a)(b): (as + 1)(bs + 1)

Table D-V

SIMULTANEOUS PITCH RATE AND NORMAL ACCELERATION AT PILOT STATION MATCHING

CONFIG	FLIGHT/ RECORD NO.	K_{q_e} ($\times 10^{-1}$)	ζ_{SP_e}	ω_{SP_e} (rad/sec)	$\tau_{\theta 2_e}$ (sec)	τ_{q_e} (sec)	COST/ NPTS	$K_{n_{z_e}}$ ($\times 10^{-1}$)	$\tau_{n_{z_e}}$ (sec)	COST/ NPTS
A1-1	F802 R09	9.77	.46	1.98	.955	.104	(1)	3.24	.123	114(1)
A2-2x	F802 R19*	15.70	1.76	2.10	.559	.210	(1)	1.79	-.174	236(1)
A3-3x	F803 R19	18.36	(2.67)	(.005)(2)	.213	.255	(1)	1.16	-.084	88(1)
B1-1	F805 R14	7.48	.52	3.99	.290	.077	5.4	1.68	.088	5.7
B1-1x	F806 R16	6.34	.79	2.73	1.13	.125	5.6	1.92	-.184	26.0
B1-2	F808 R07	7.10	.67	3.94	.341	.081	5.3	1.45	.066	8.5
B1-3	F808 R27*	8.39	(.514)	(.031)(2)	.238	.140	9.7	1.86	.170	12.6
B2-2x	F808 R12	8.33	.98	2.17	.638	.128	16.5	1.63	-.165	20.5
B3-3	F804 R09	7.48	1.20	2.07	.349	.098	1.9	1.69	.088	4.0
B3-3x	F806 R29	5.75	1.06	1.56	.796	.130	2.8	1.48	-.160	11.7
C1-1	F808 R18	6.57	.86	6.42	.0001	-.048	17.9	1.59	.082	13.9
C2-2	F806 R23	7.28	1.11	5.21	.0001	.020	3.0	1.93	.123	2.1
C2-2x	F808 R24	6.66	.73	3.72	.163	.094	2.3	1.58	-.040	2.7
C3-3	F804 R32	6.94	1.21	3.16	.0001	-.004	2.7	1.72	.094	2.7
C3-3x	F808 R37	6.77	1.03	2.82	.129	.095	4.3	1.59	-.013	7.9
Other records:										
C1-1	F808 R17*	7.12	.69	7.21	.0001	-.019	5.9	1.86	.085	5.4
C1-1	F808 R18**	7.09	.59	6.95	.0001	-.011	0.9	1.76	.094	1.8

* Task Record

● Frequency range .1 to 10. rps except ** .7 to 11. rps

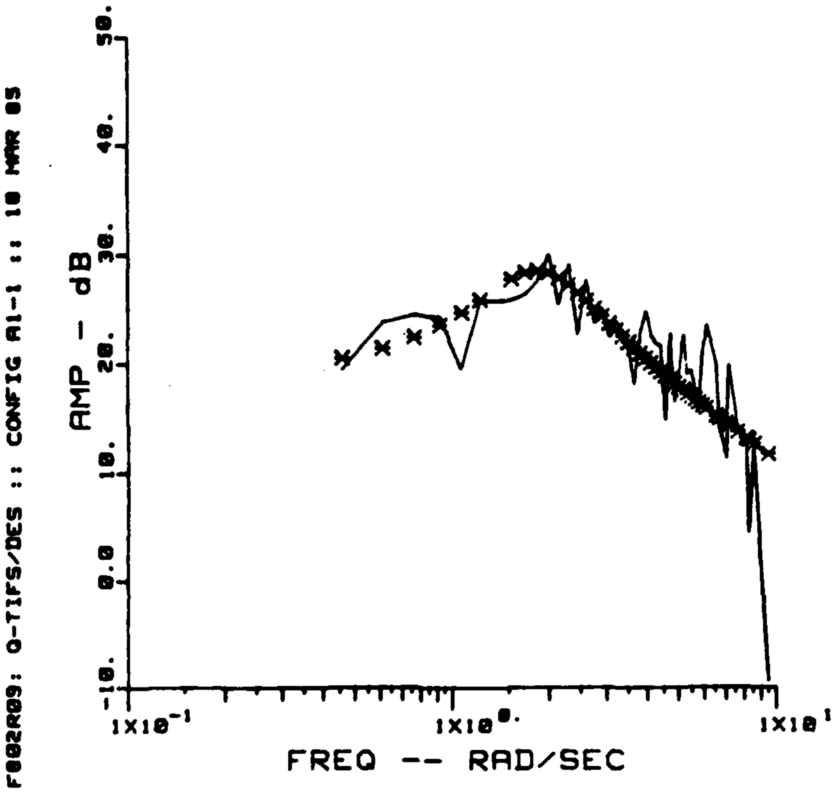
(1) Extremely poor data quality; see text

(2) Two real roots, (a)(b): (as + 1)(bs + 1)

Table D-VI

$(\dot{h}_p/\theta)$ EQUIVALENT SYSTEMS RESULTS

CONFIGURATION	$\tau_{\theta_{2eff}}$	$\ell_{p_{eff}}$	COST/NPTS
A1-1	1.3415	0.0	15.6
A2-2x (FFT)	.7559	16.9	80.1
(Task)	-.6018	-8.0	158.0
A3-3x	4.413	13.1	62.5
B1-1	.3023	0.0	4.7
B1-1x	.4489	28.9	0.9
B1-2	.2785	0.0	3.0
B1-3	.2735	0.0	5.9
B2-2x	.3220	41.5	1.7
B3-3	.3824	0.0	0.6
B3-3x	.3802	30.1	2.9
C1-1	-.0087	-71.1	5.7
C2-2	-.0543	-66.9	0.7
C2-2x	.0907	30.4	0.4
C3-3	-.0387	-63.1	0.3
C3-3x	.0461	21.5	1.3



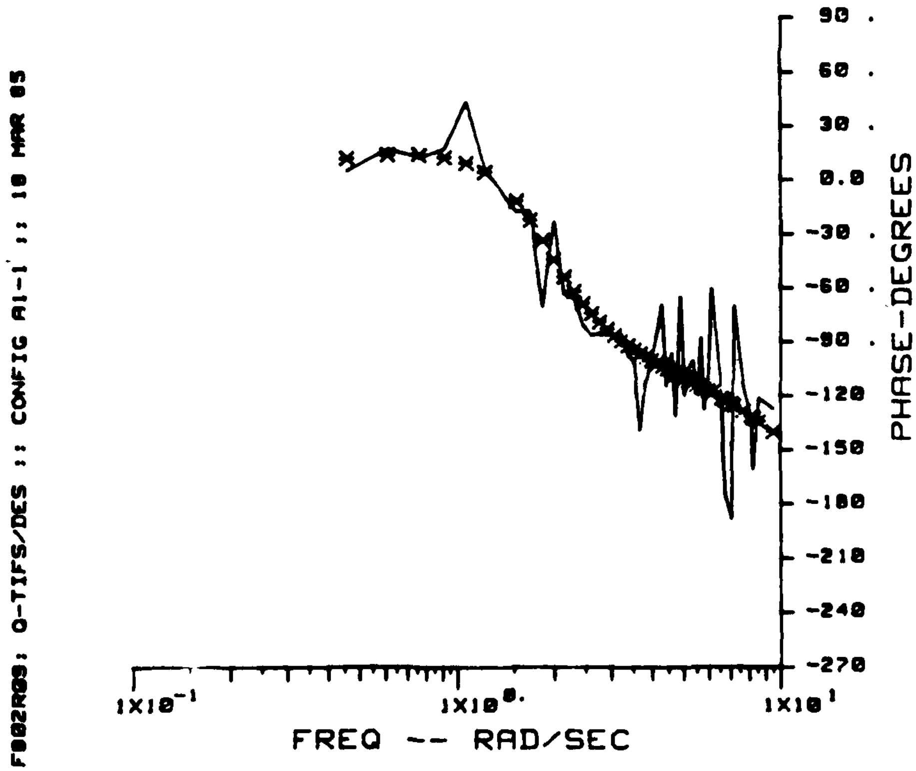
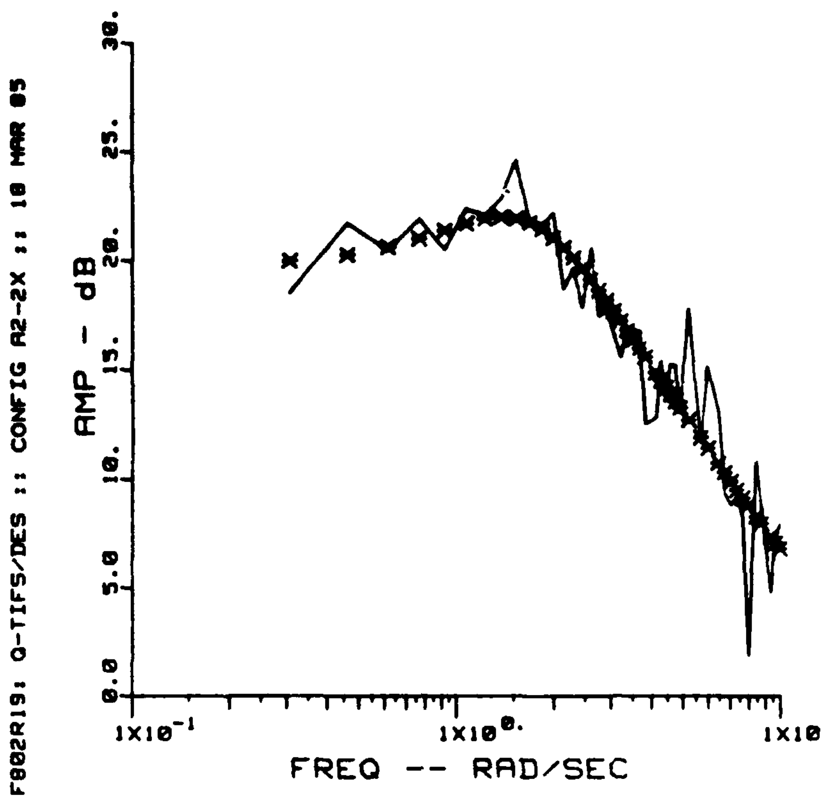


Figure D-1. (q/F_{es}) EQUIVALENT SYSTEM - τ_{θ_2} FREE;
CONFIGURATION A1-1, FLIGHT 802, RECORD 09



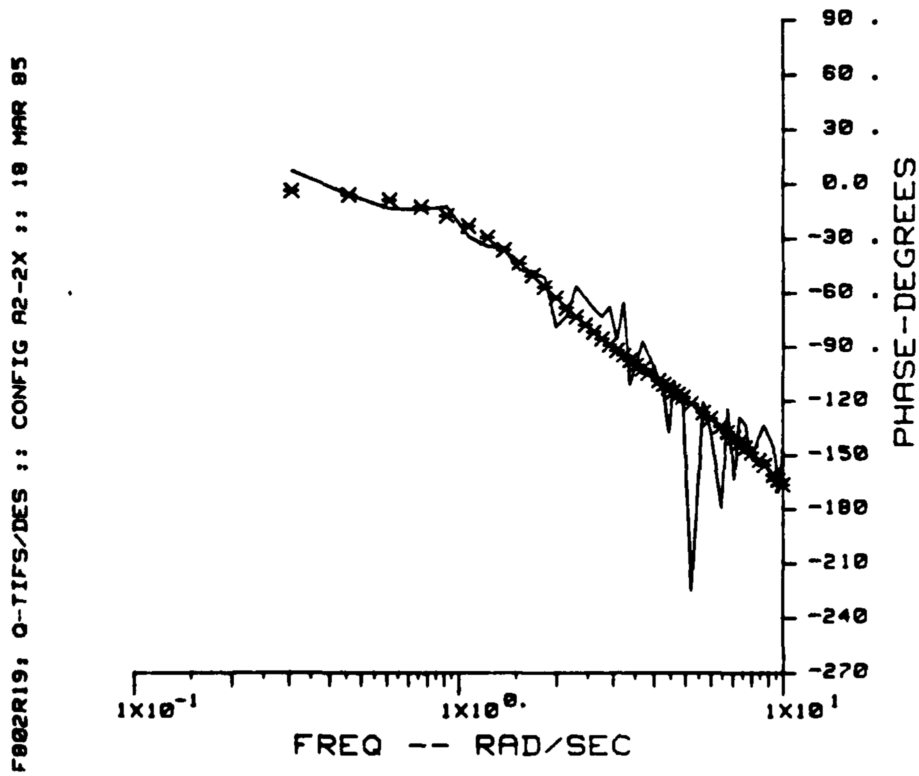
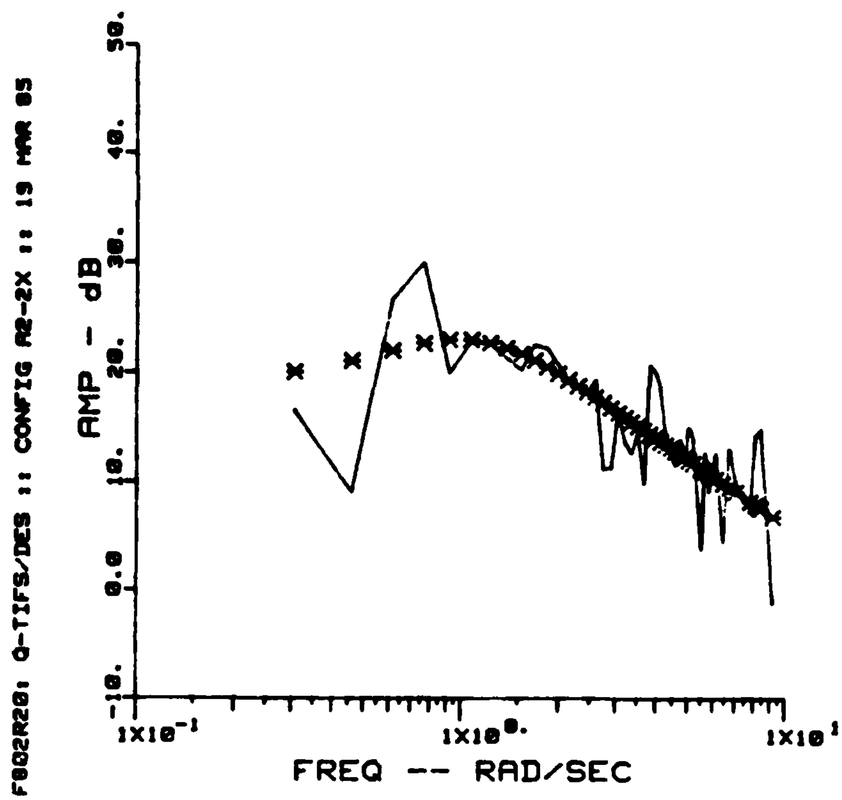


Figure D-2. (q/F_{es}) EQUIVALENT SYSTEM - τ_{θ_2} FREE; CONFIGURATION A2-2x, FLIGHT 802, RECORD 19



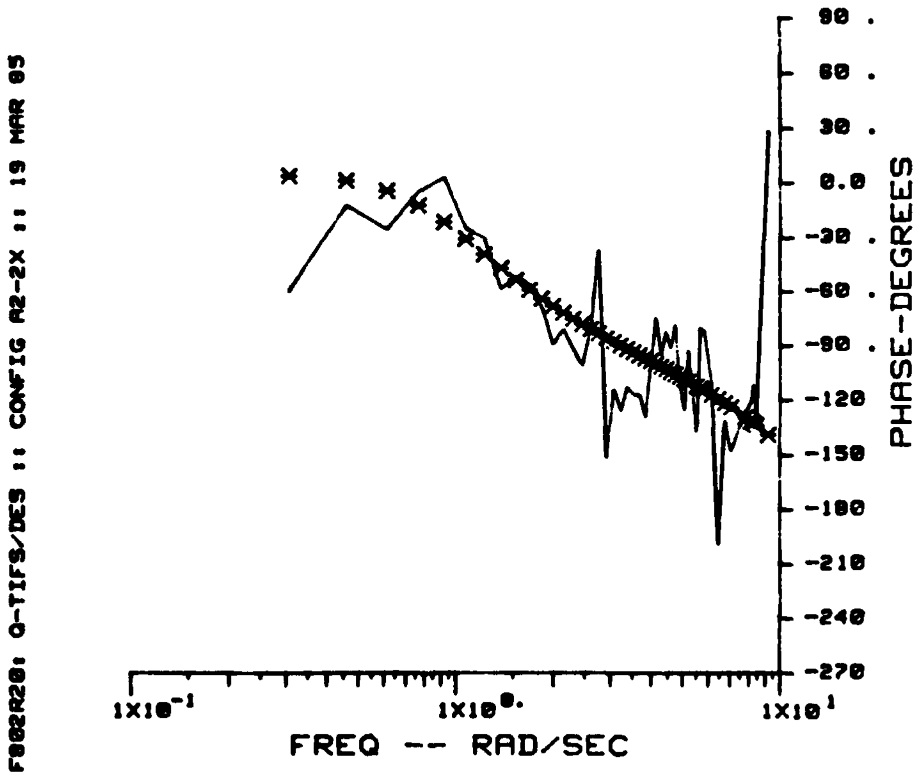
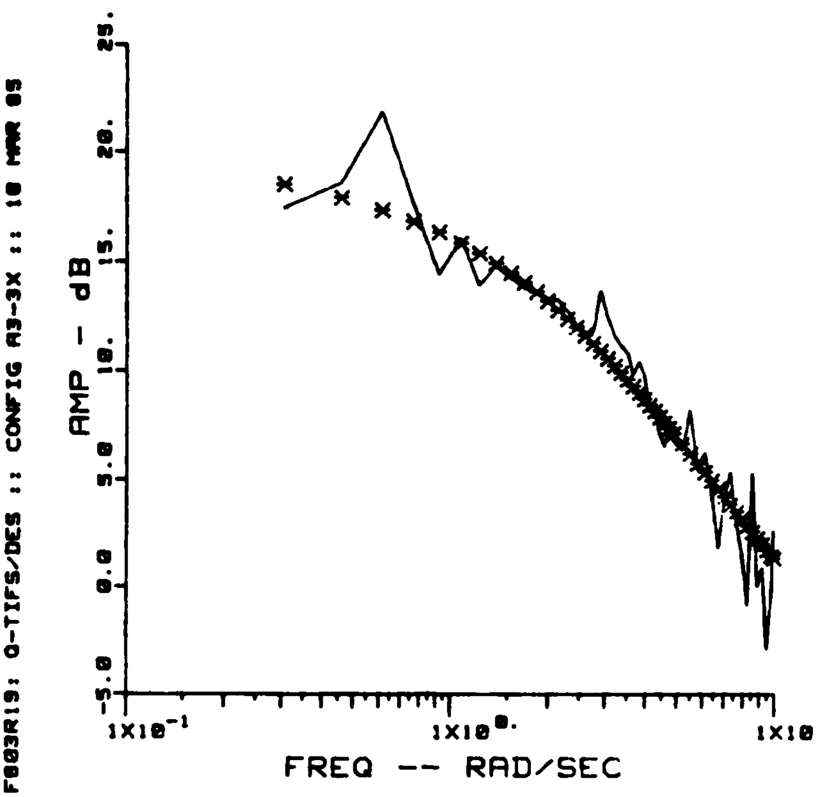


Figure D-3. (q/F_{es}) EQUIVALENT SYSTEM - τ_{e_2} FREE; CONFIGURATION A2-2x, FLIGHT 802, RECORD 20



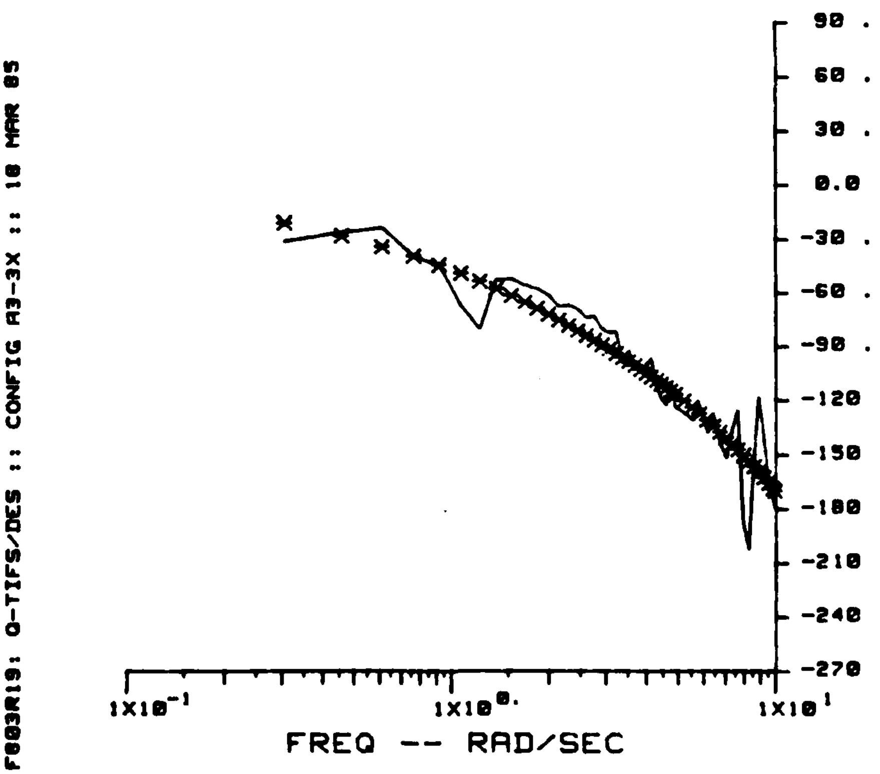
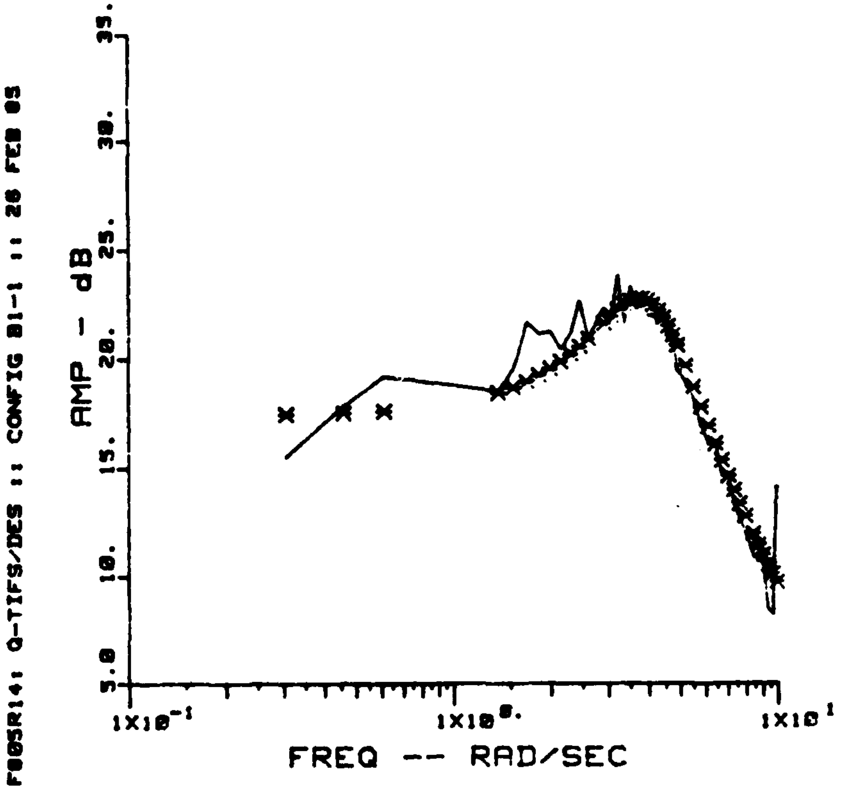


Figure D-4. (q/F_{es}) EQUIVALENT SYSTEM - τ_{θ_2} FREE; CONFIGURATION A3-3x, FLIGHT 803, RECORD 19



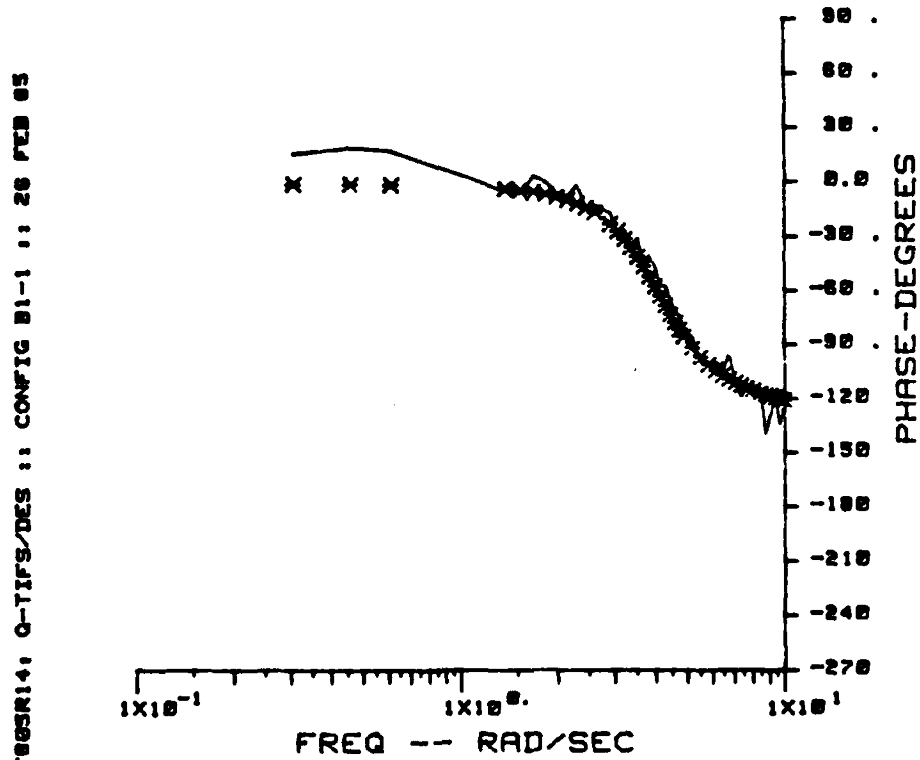
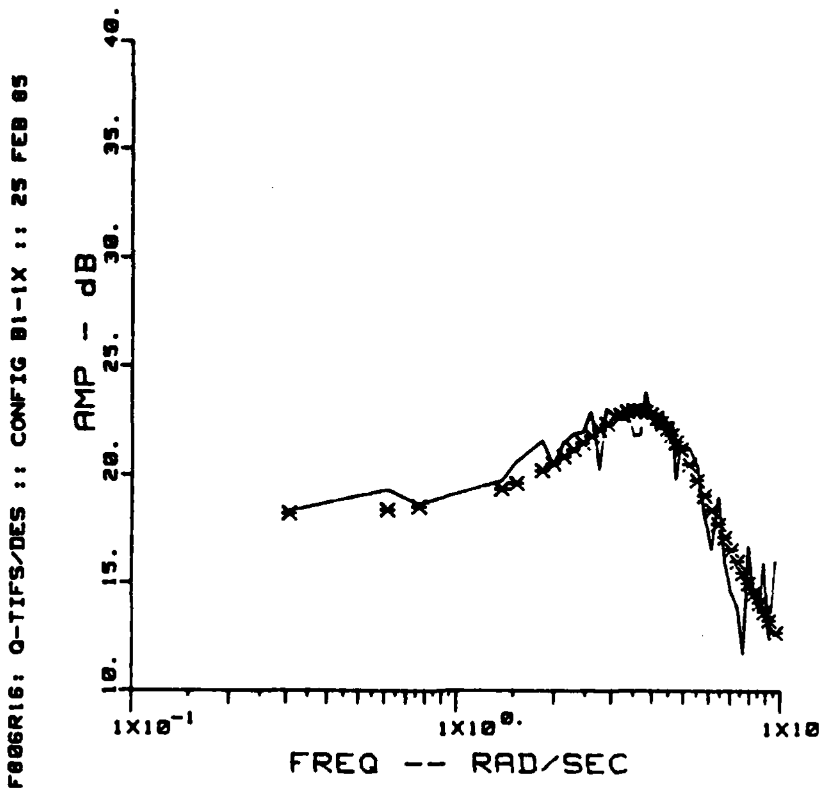


Figure D-5. (q/F_{es}) EQUIVALENT SYSTEM - τ_{θ_2} FREE; CONFIGURATION B1-1x, FLIGHT 805, RECORD 14



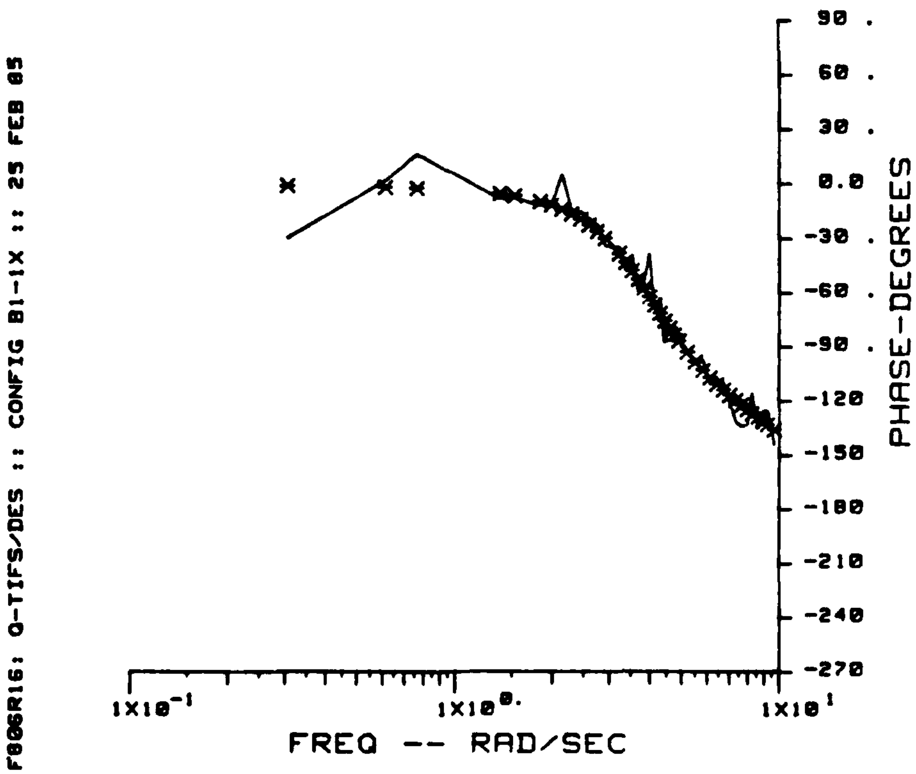
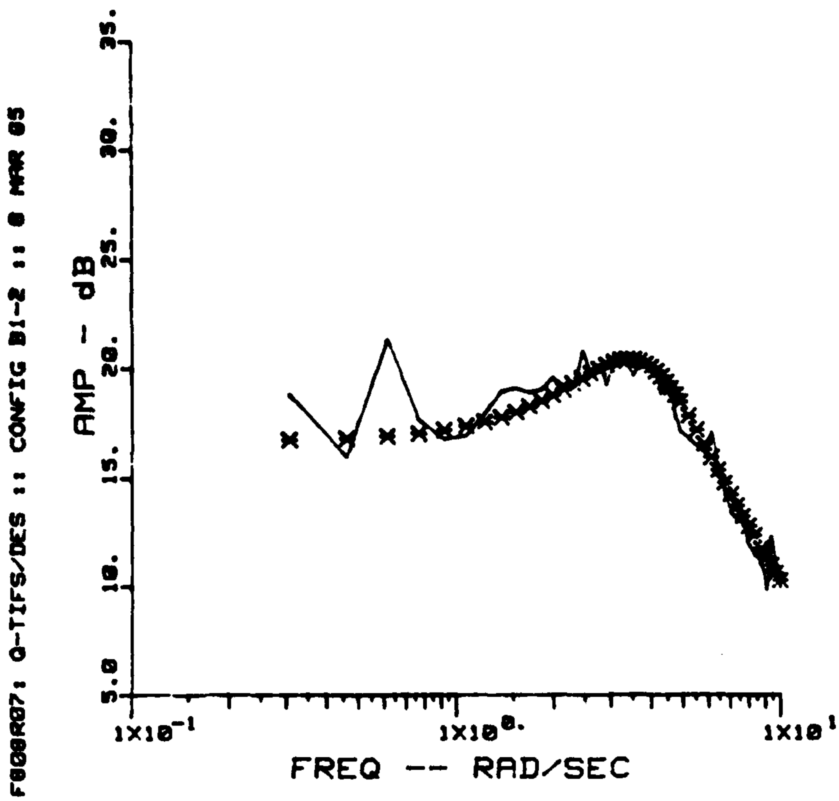


Figure D-6. (q/F_{es}) EQUIVALENT SYSTEM - τ_{θ_2} FREE; CONFIGURATION B1-1x, FLIGHT 806, RECORD 16



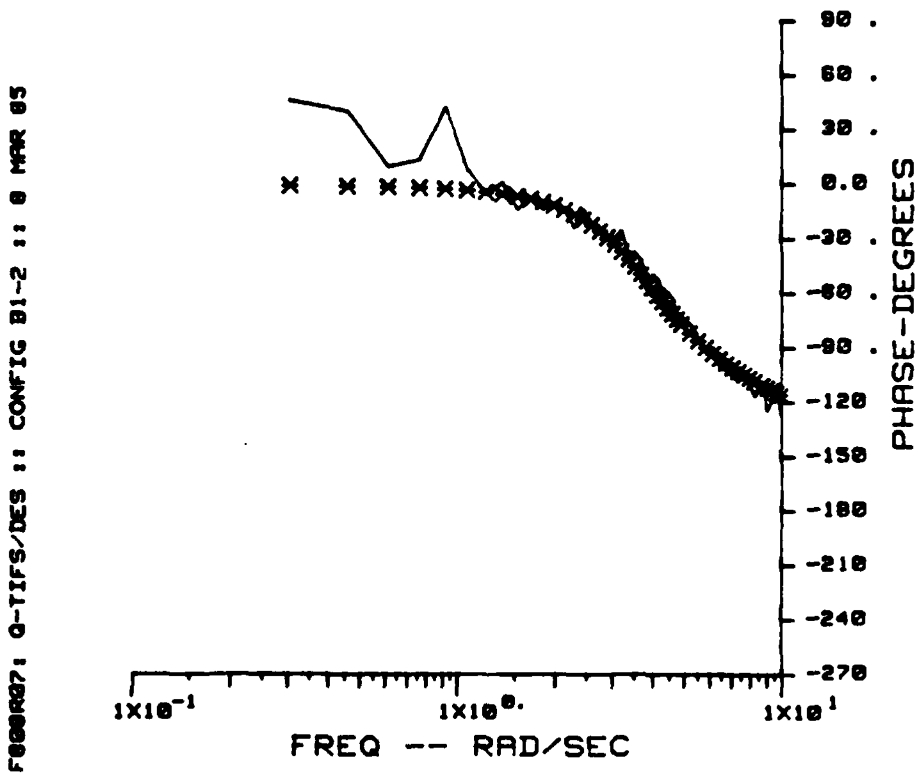
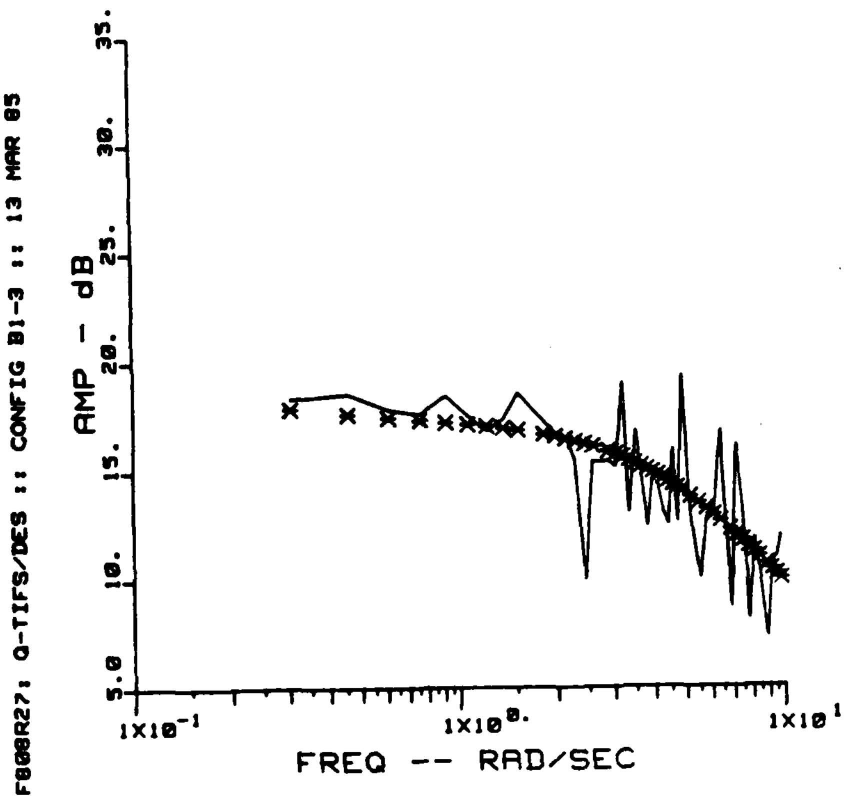


Figure D-7. (q/F_{es}) EQUIVALENT SYSTEM - τ_{θ_2} FREE; CONFIGURATION B1-2, FLIGHT 808, RECORD 07



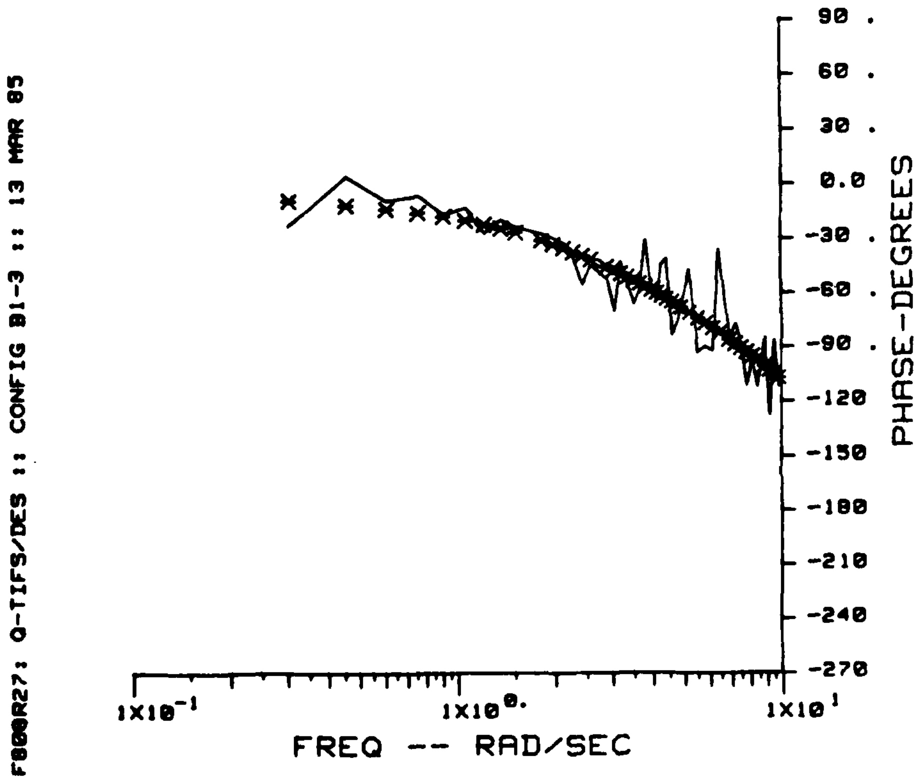


Figure D-8. (q/F_{es}) EQUIVALENT SYSTEM - τ_{θ_2} FREE; CONFIGURATION B1-3, FLIGHT 808, RECORD 27

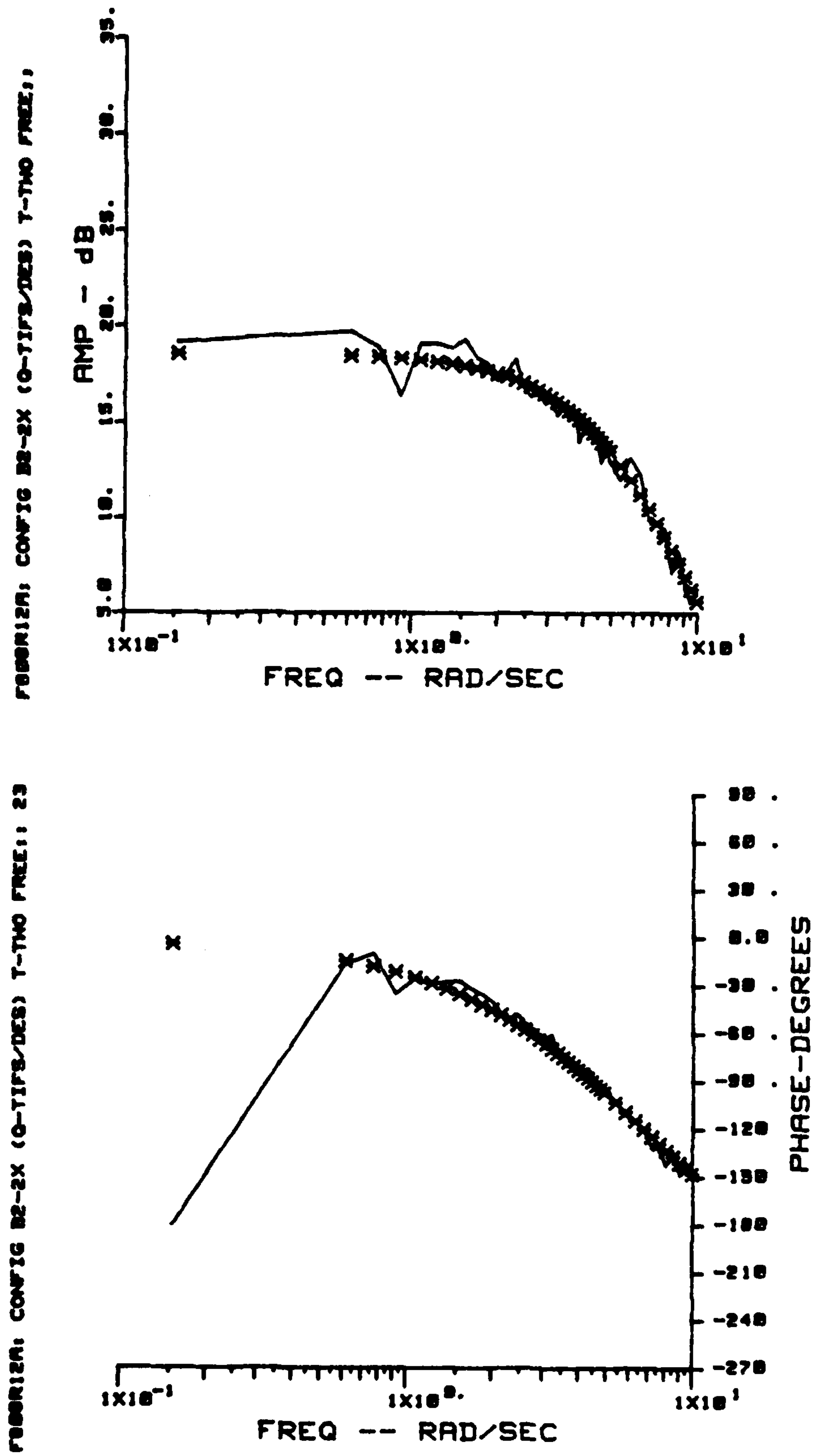
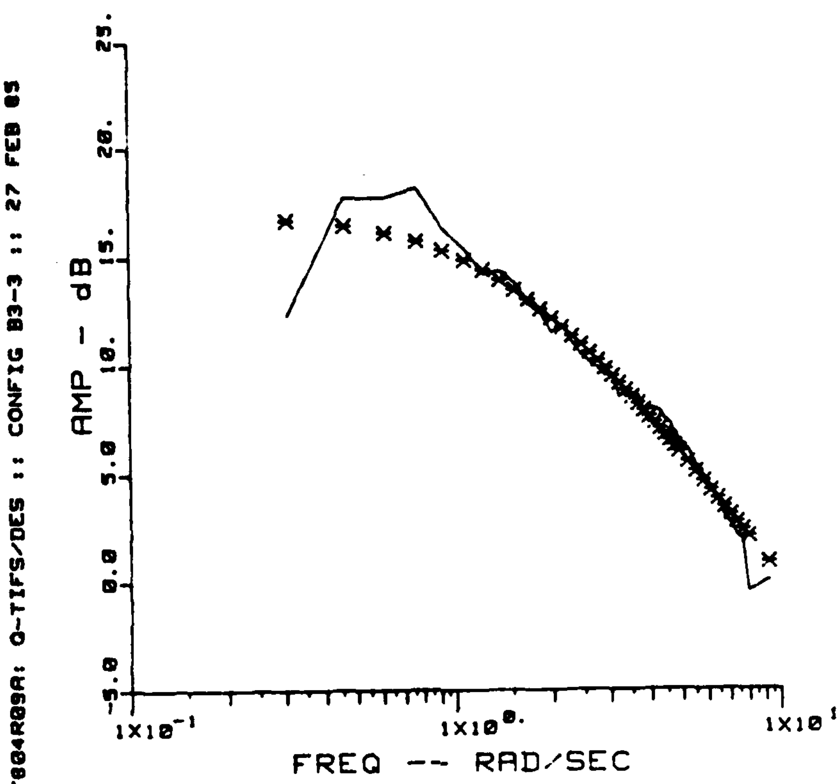


Figure D-9. (q/F_{es}) EQUIVALENT SYSTEM - τ_{θ_2} FREE; CONFIGURATION B2-2x, FLIGHT 808, RECORD 12



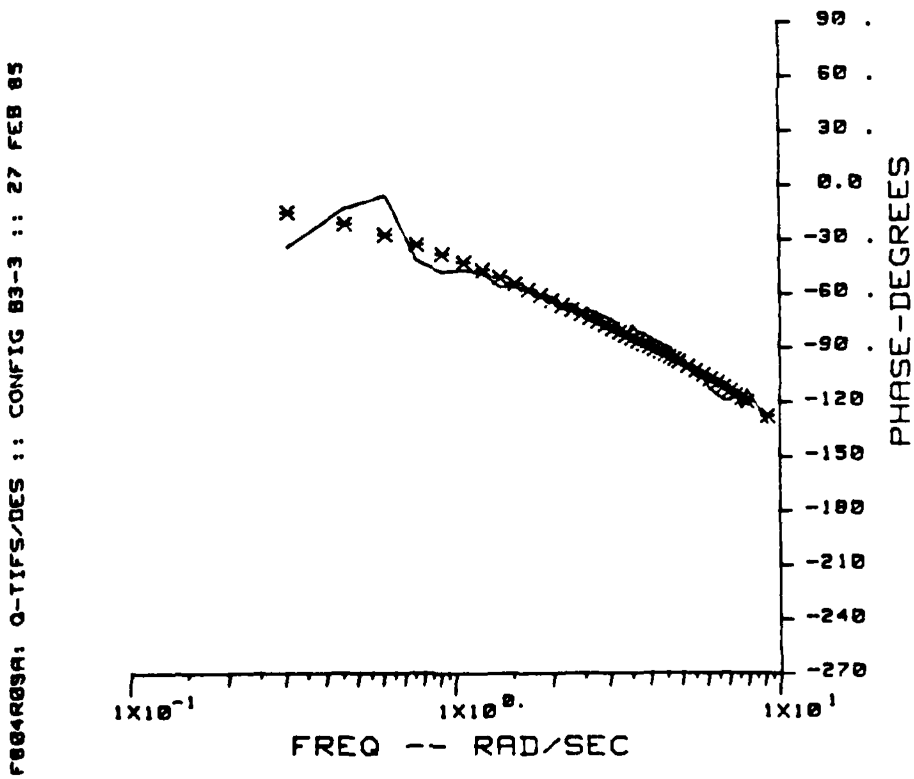
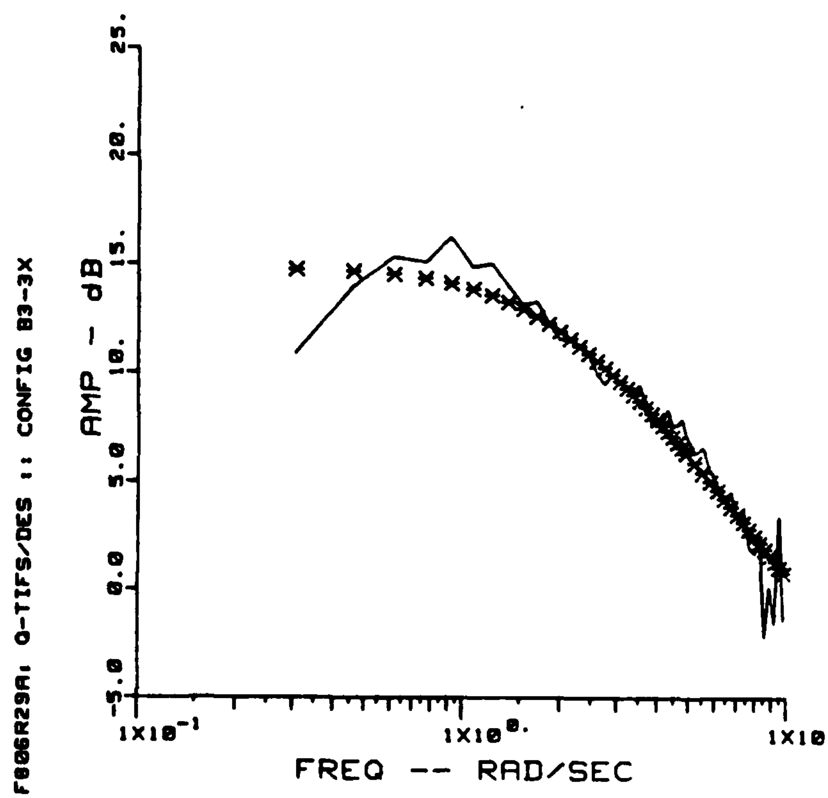


Figure D-10. (q/F_{es}) EQUIVALENT SYSTEM - τ_{θ_2} FREE; CONFIGURATION B3-3, FLIGHT 804, RECORD 09



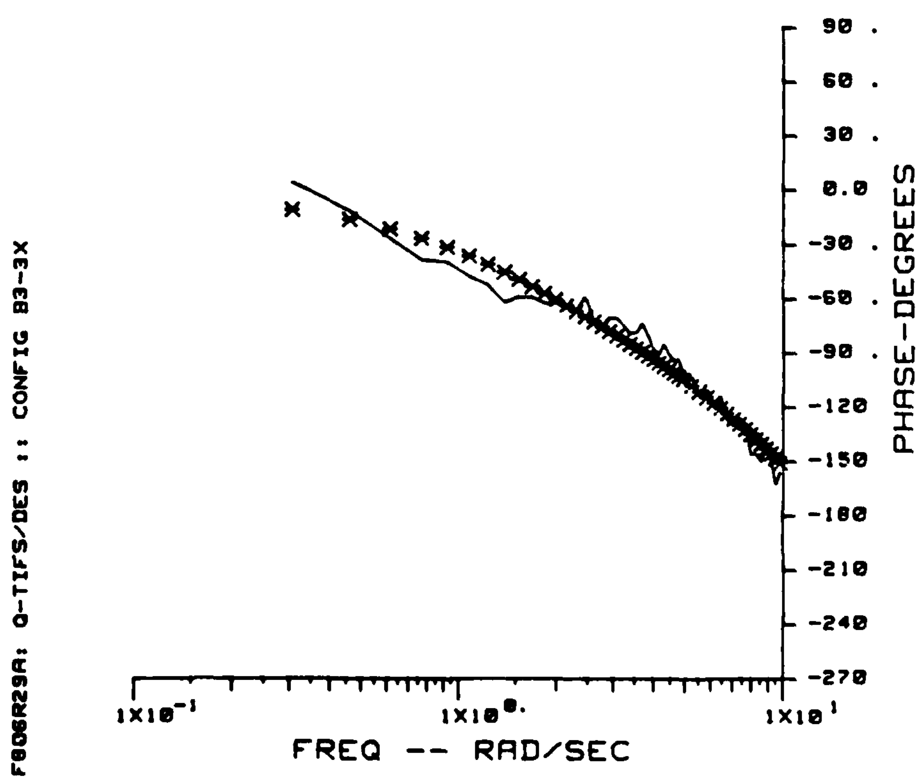


Figure D-11. (q/F_{es}) EQUIVALENT SYSTEM - τ_{θ_2} FREE; CONFIGURATION B3-3x, FLIGHT 806, RECORD 29

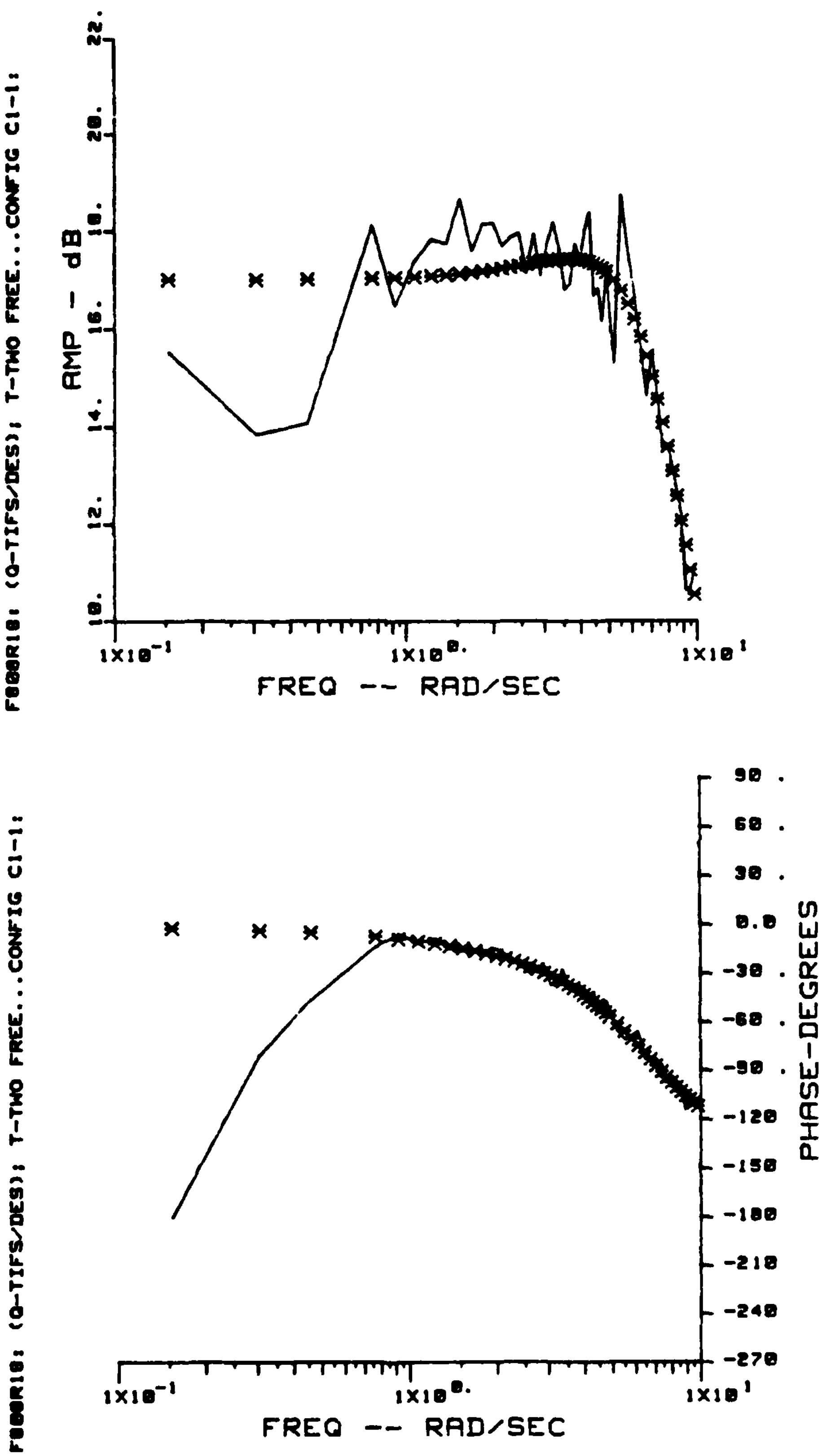


Figure D-12. (q/F_{es}) EQUIVALENT SYSTEM - τ_{θ_2} FREE; CONFIGURATION C1-1, FLIGHT 808, RECORD 18

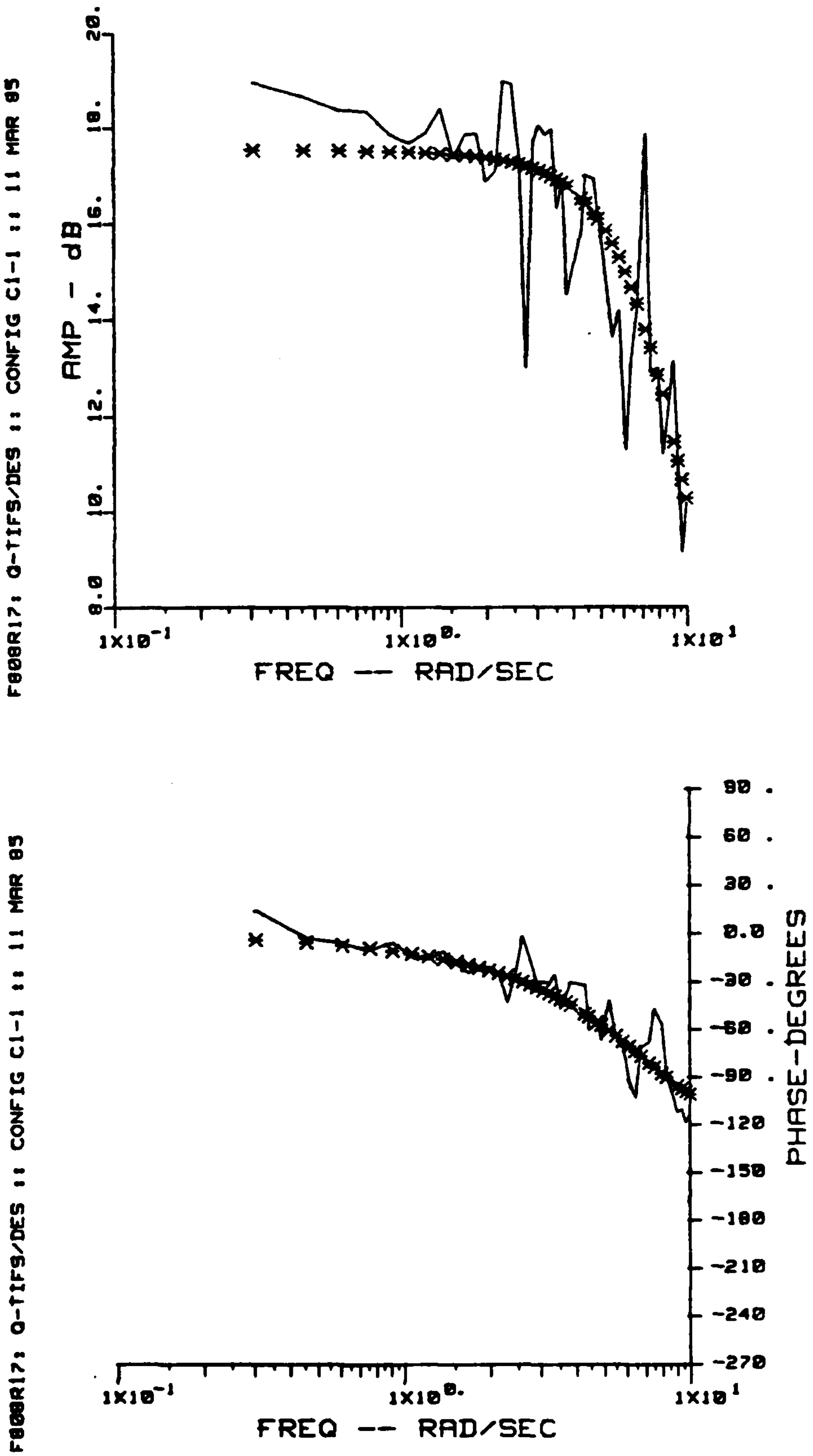


Figure D-13. (q/F_{es}) EQUIVALENT SYSTEM - τ_{θ_2} FREE; CONFIGURATION C1-1, FLIGHT 808, RECORD 17

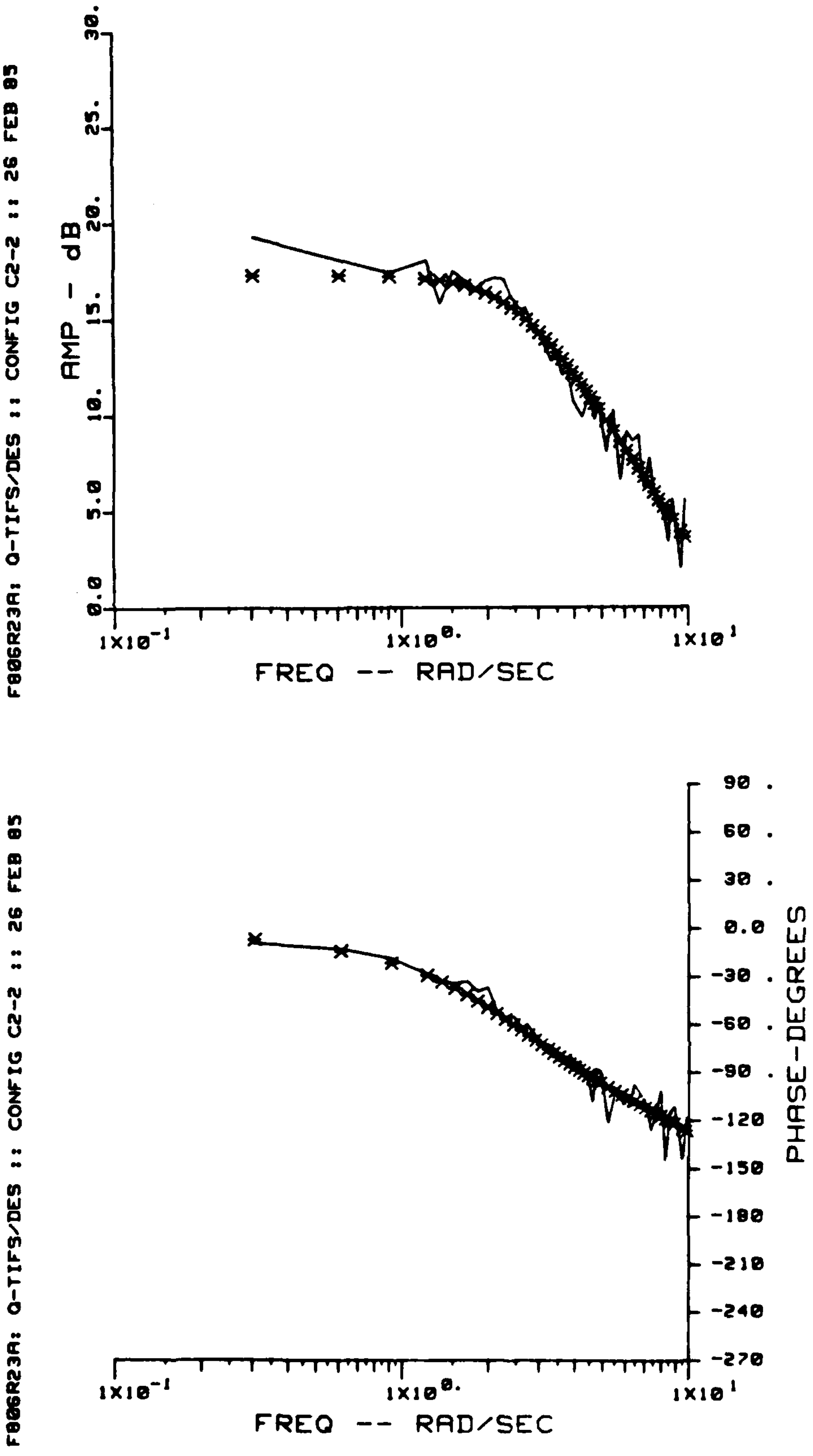
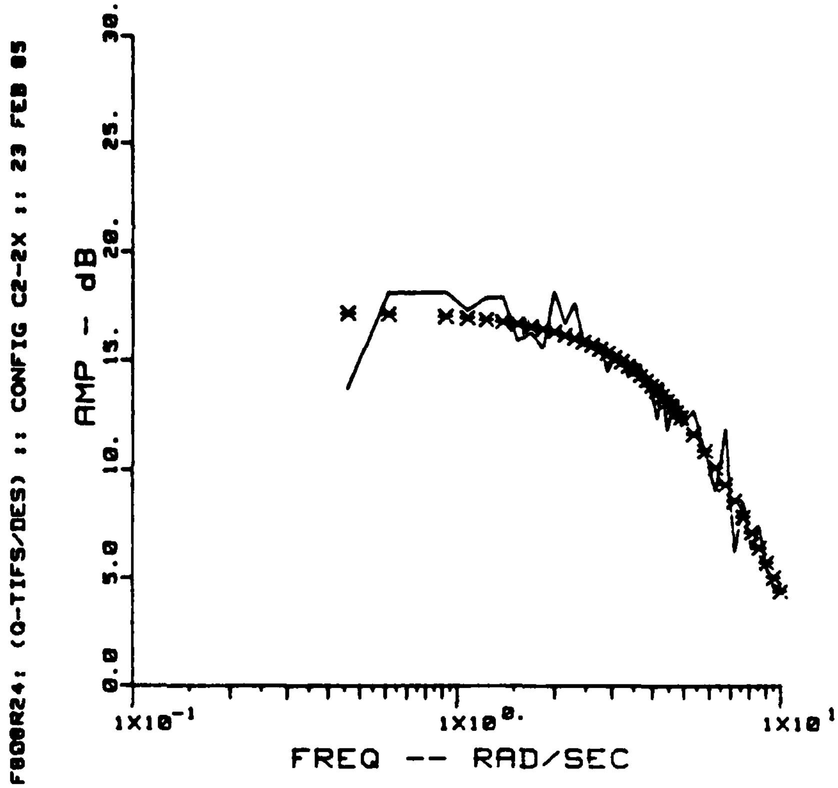


Figure D-14. (q/F_{es}) EQUIVALENT SYSTEM - τ_{θ_2} FREE; CONFIGURATION C2-2, FLIGHT 806, RECORD 23



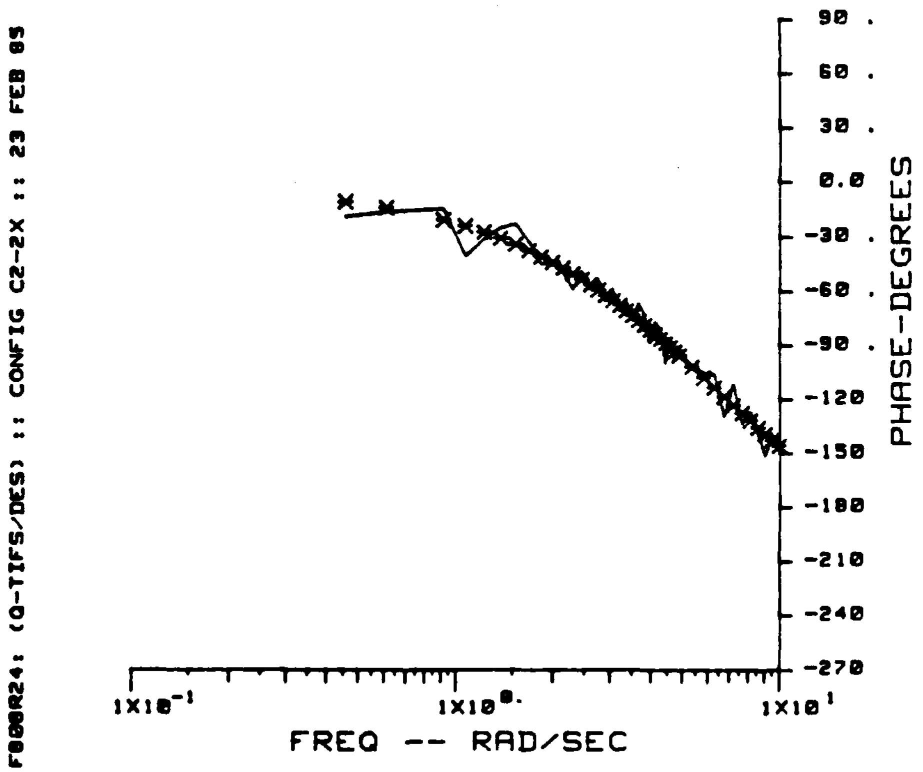
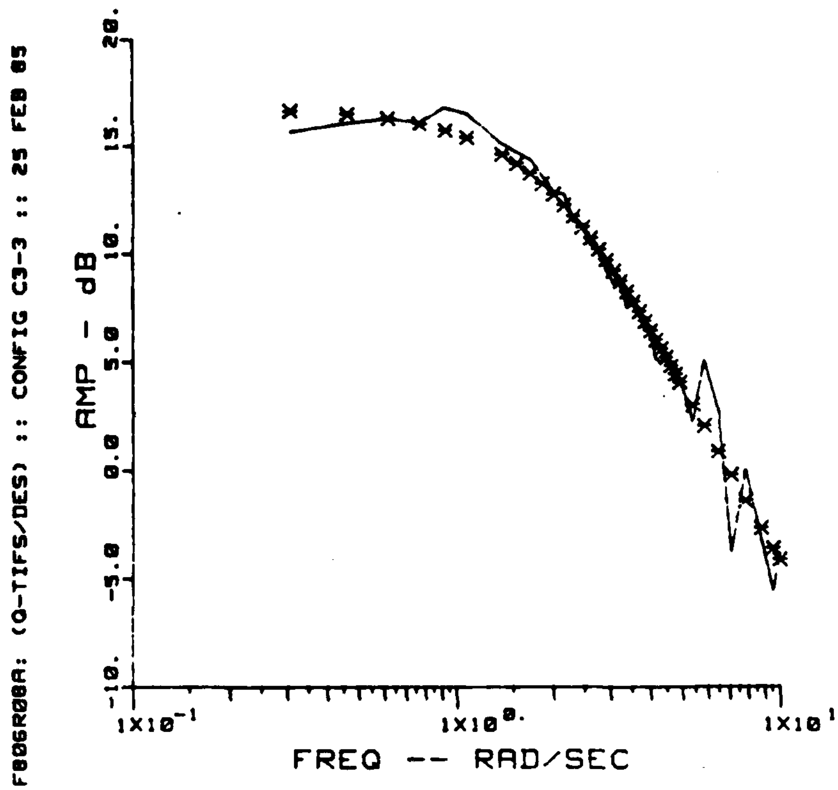


Figure D-15. (q/F_{es}) EQUIVALENT SYSTEM - τ_{θ_2} FREE; CONFIGURATION C2-2x, FLIGHT 808, RECORD 24



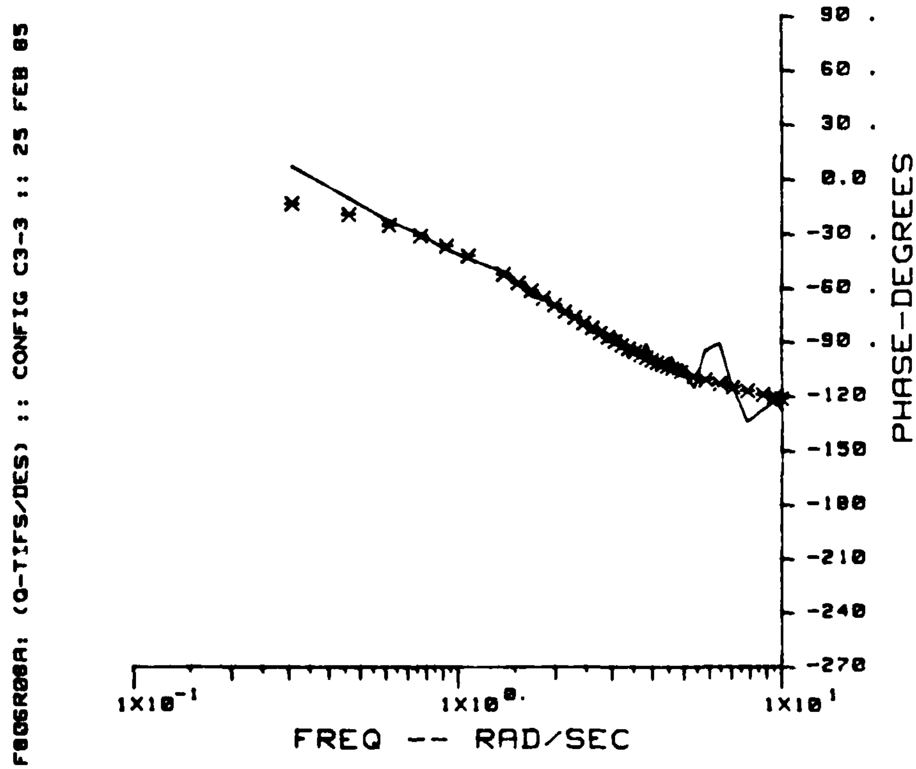
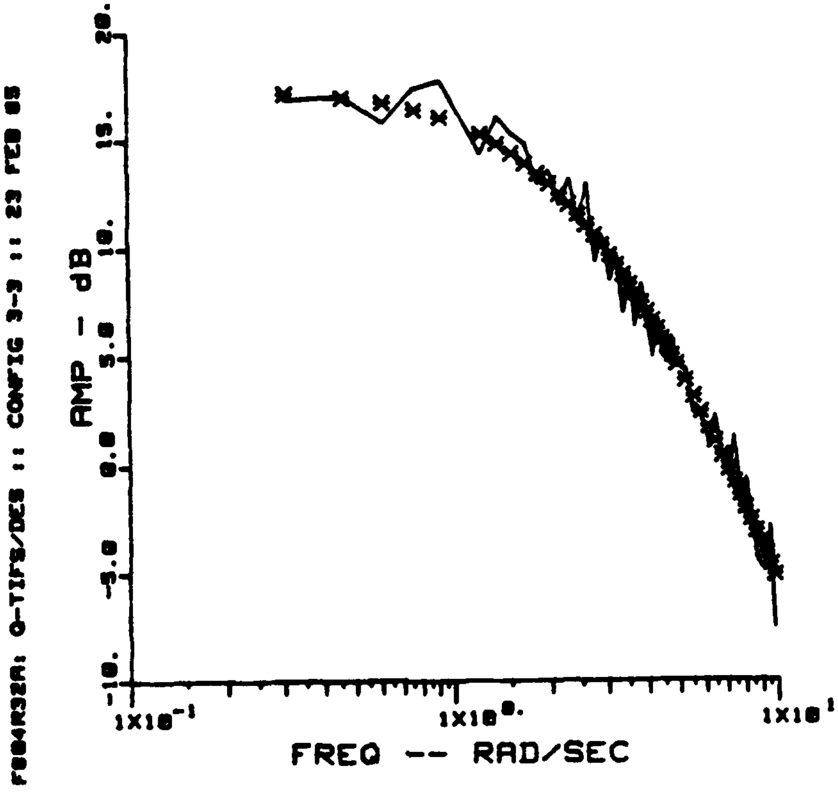


Figure D-16. (q/F_{es}) EQUIVALENT SYSTEM - τ_{θ_2} FREE;
CONFIGURATION C3-3, FLIGHT 806, RECORD 08



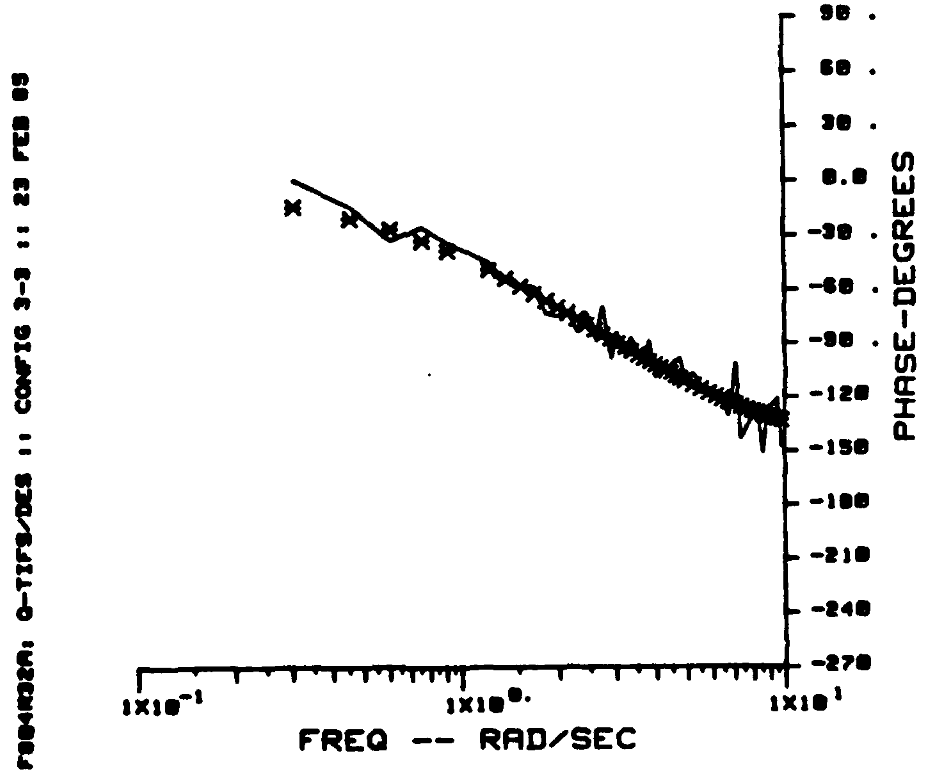


Figure D-17. (q/F_{es}) EQUIVALENT SYSTEM - τ_{θ_2} FREE; CONFIGURATION C3-3, FLIGHT 804, RECORD 32

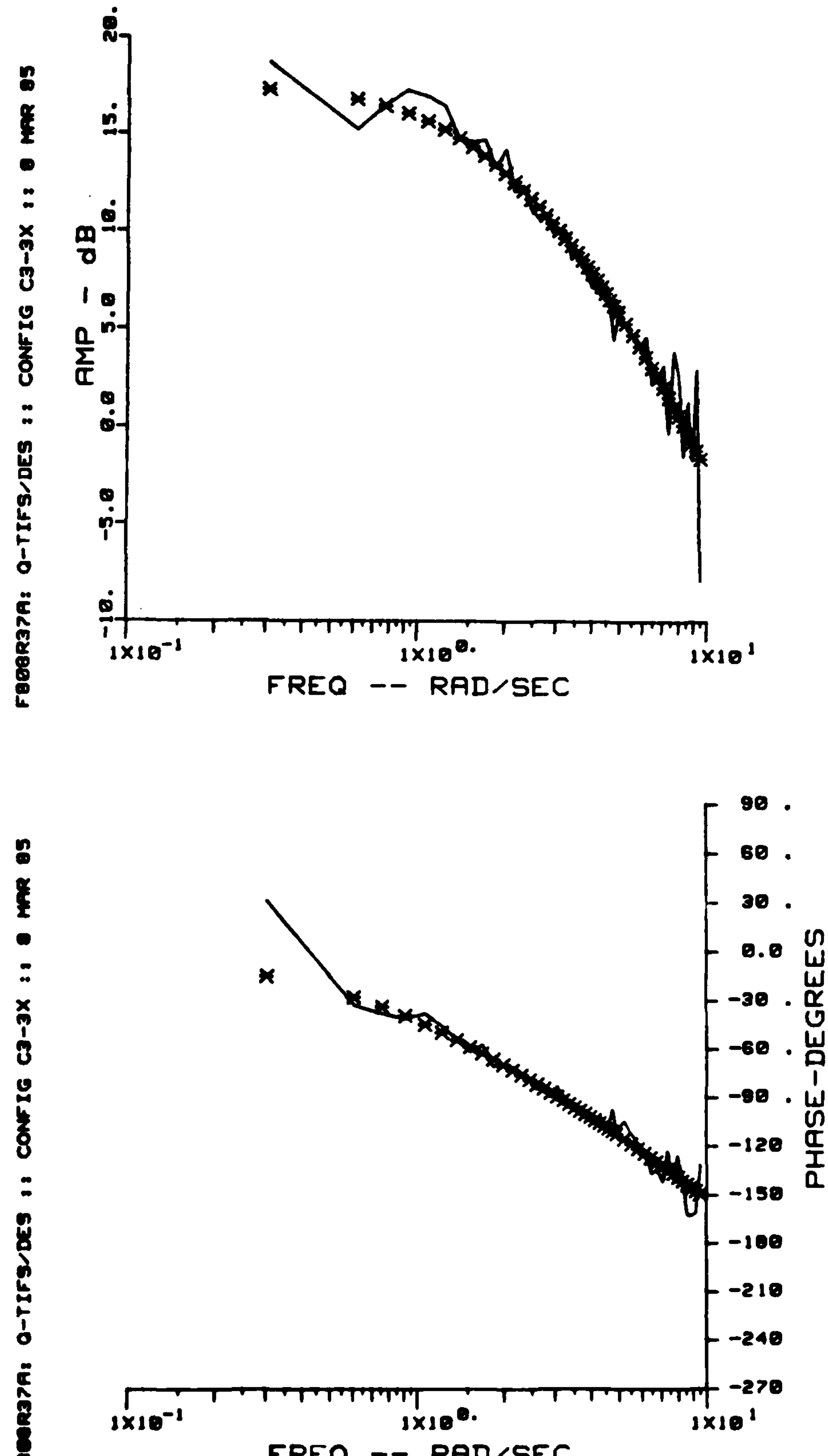
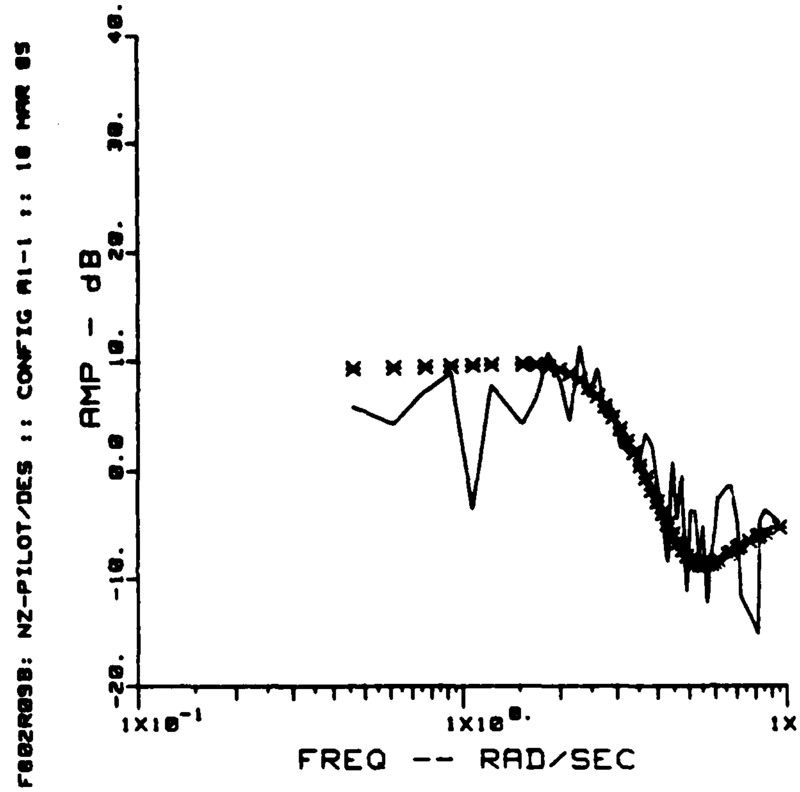


Figure D-18. (q/F_{es}) EQUIVALENT SYSTEM - τ_{θ_2} FREE; CONFIGURATION C3-3x, FLIGHT 808, RECORD 37



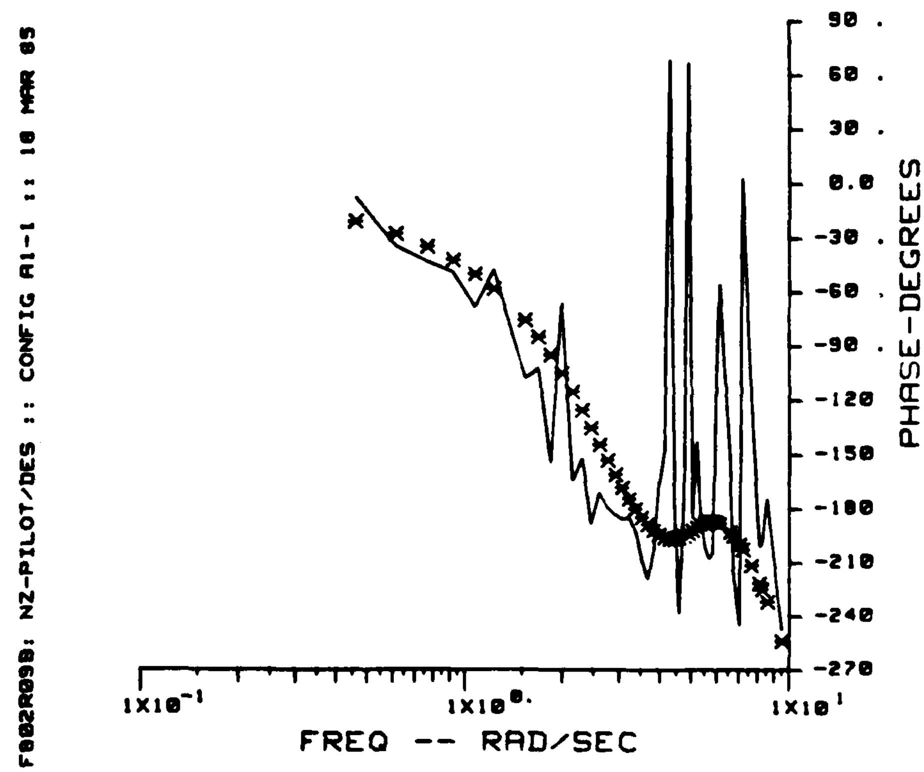
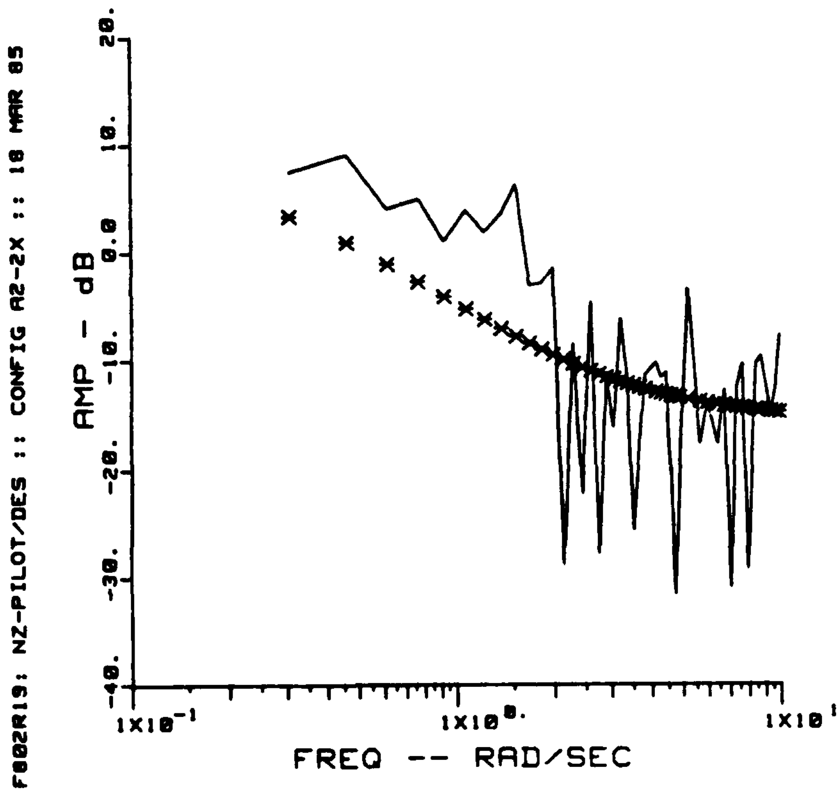


Figure D-19. (n_{z_p}/F_{es}) **EQUIVALENT SYSTEM; CONFIGURATION A1-1, FLIGHT 802, RECORD 09**



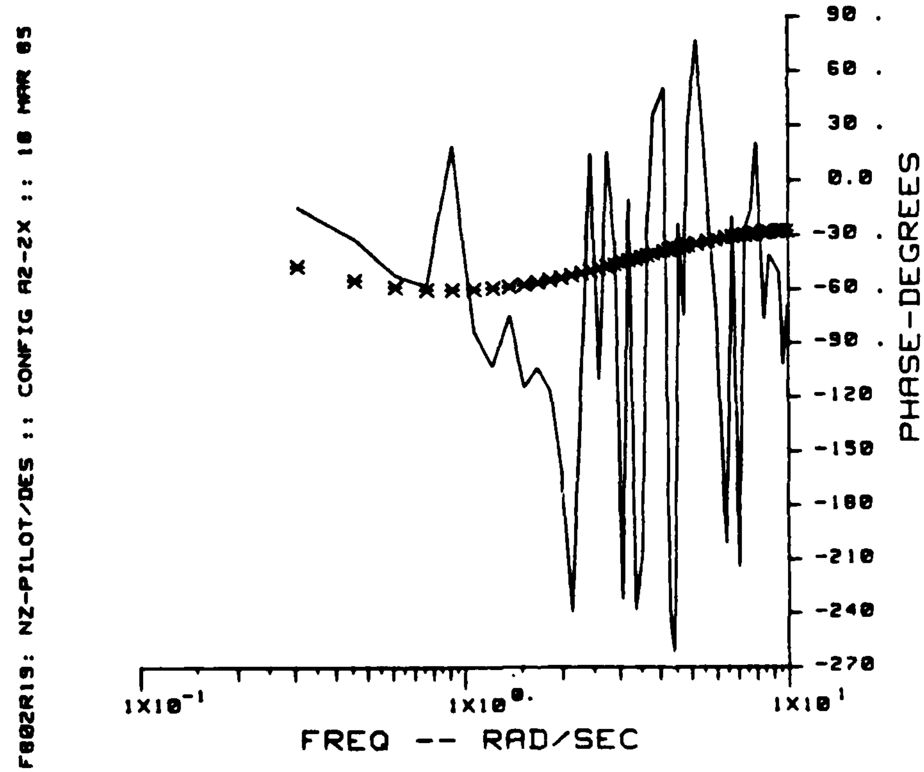


Figure D-20. (n_{z_p}/F_{es}) EQUIVALENT SYSTEM; CONFIGURATION A2-2x, FLIGHT 802, RECORD 19

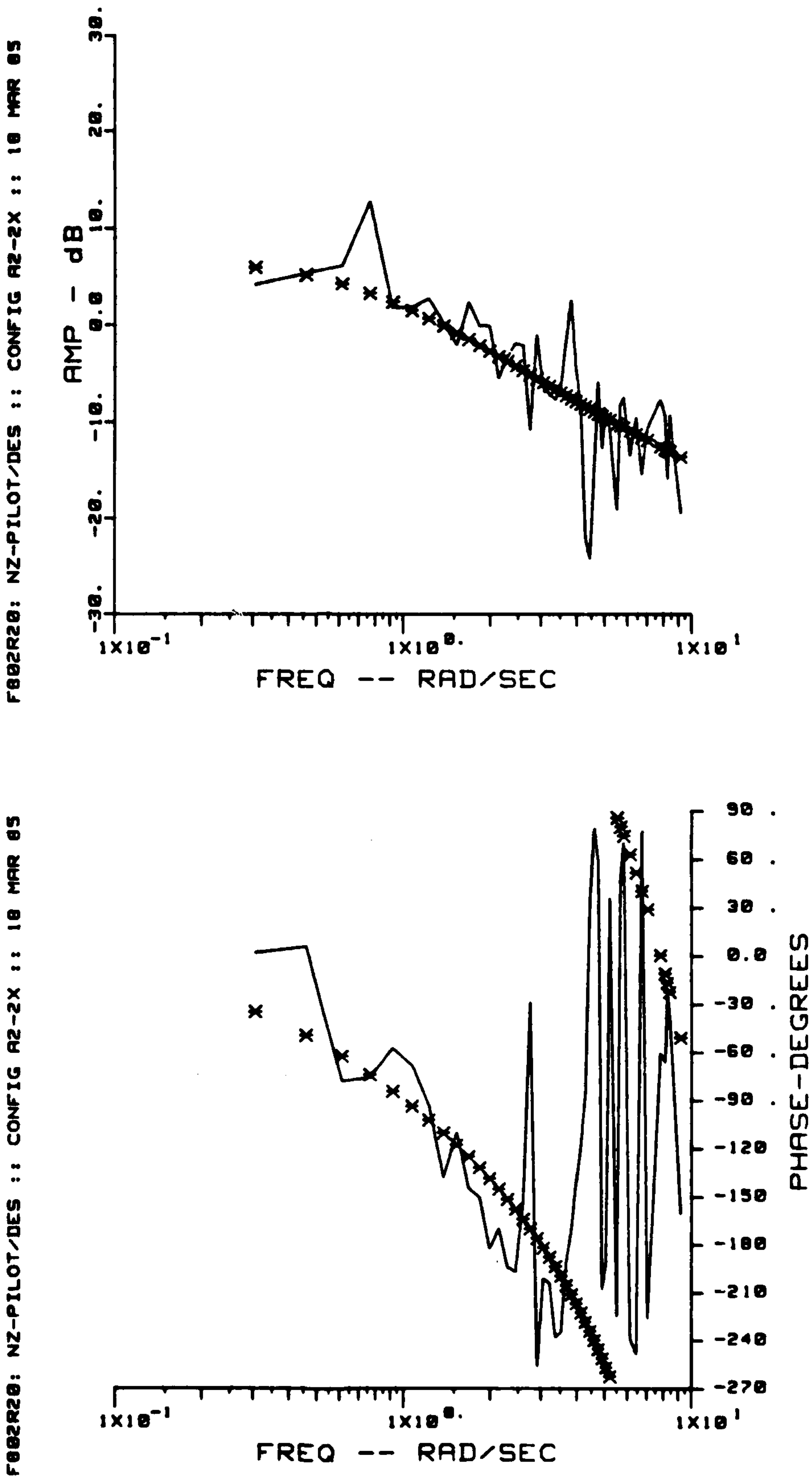
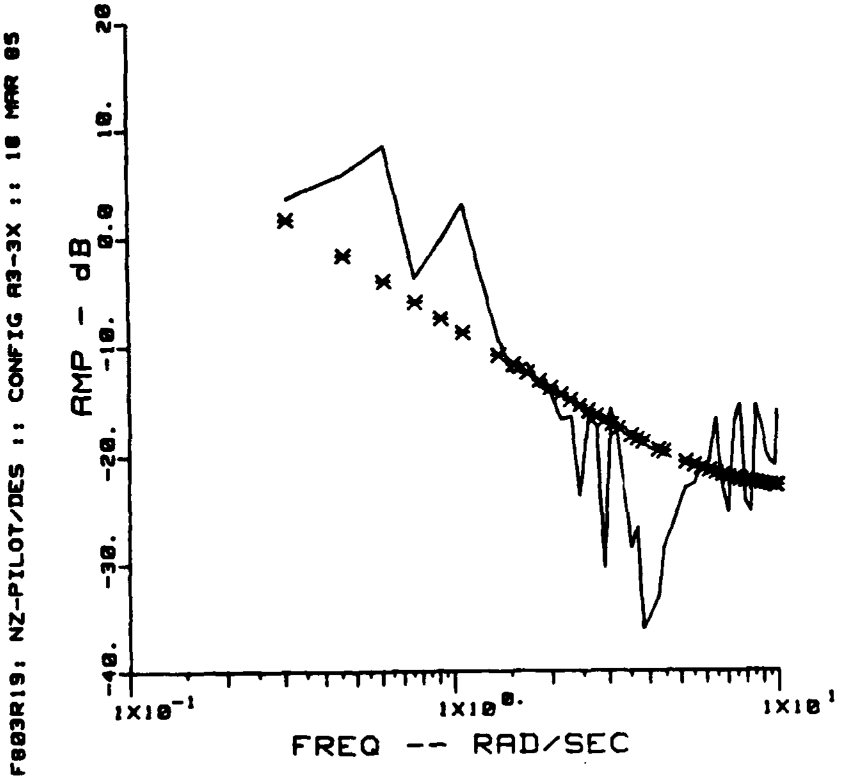


Figure D-21. (n_{z_p}/F_{es}) EQUIVALENT SYSTEM; CONFIGURATION A2-2x, FLIGHT 802, RECORD 20



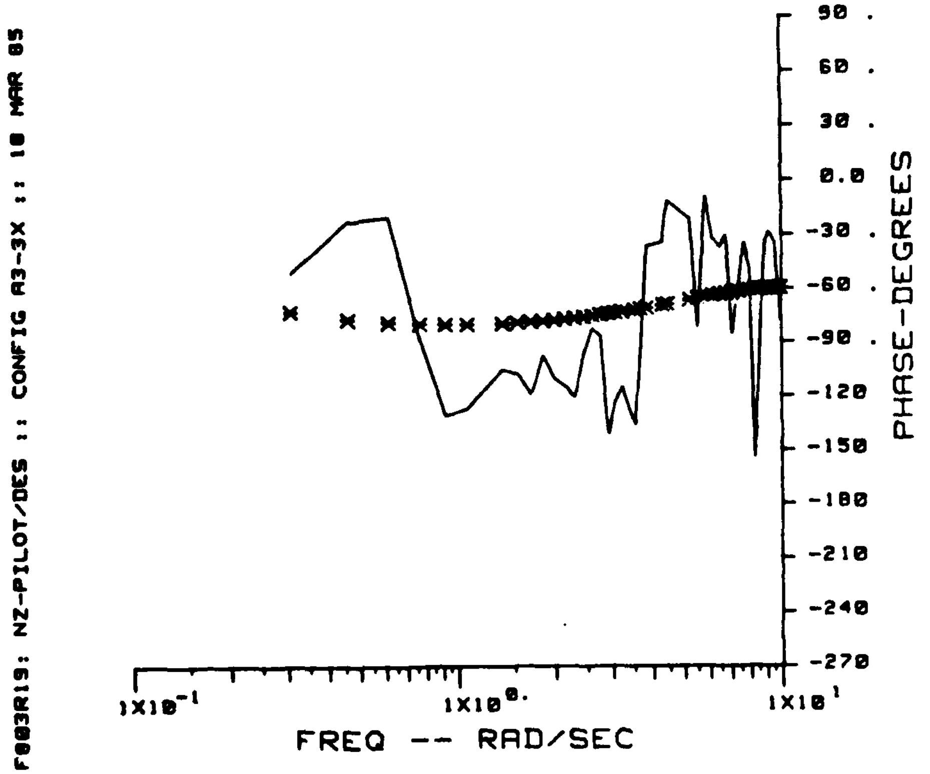


Figure D-22. (n_{z_p}/F_{es}) EQUIVALENT SYSTEM; CONFIGURATION A3-3x, FLIGHT 803, RECORD 19

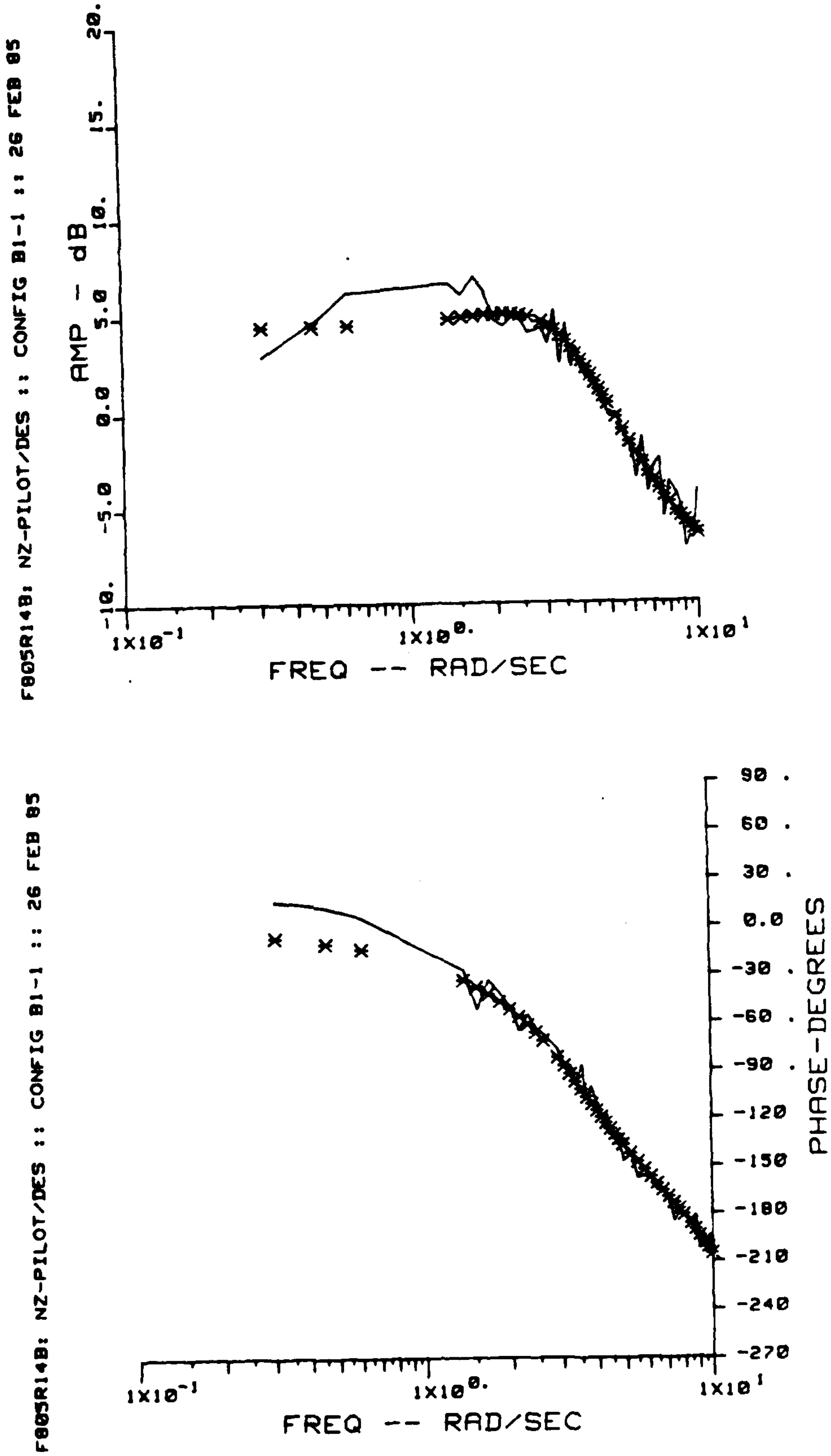


Figure D-23. (n_{z_p}/F_{es}) **EQUIVALENT SYSTEM; CONFIGURATION B1-1, FLIGHT 805, RECORD 14**

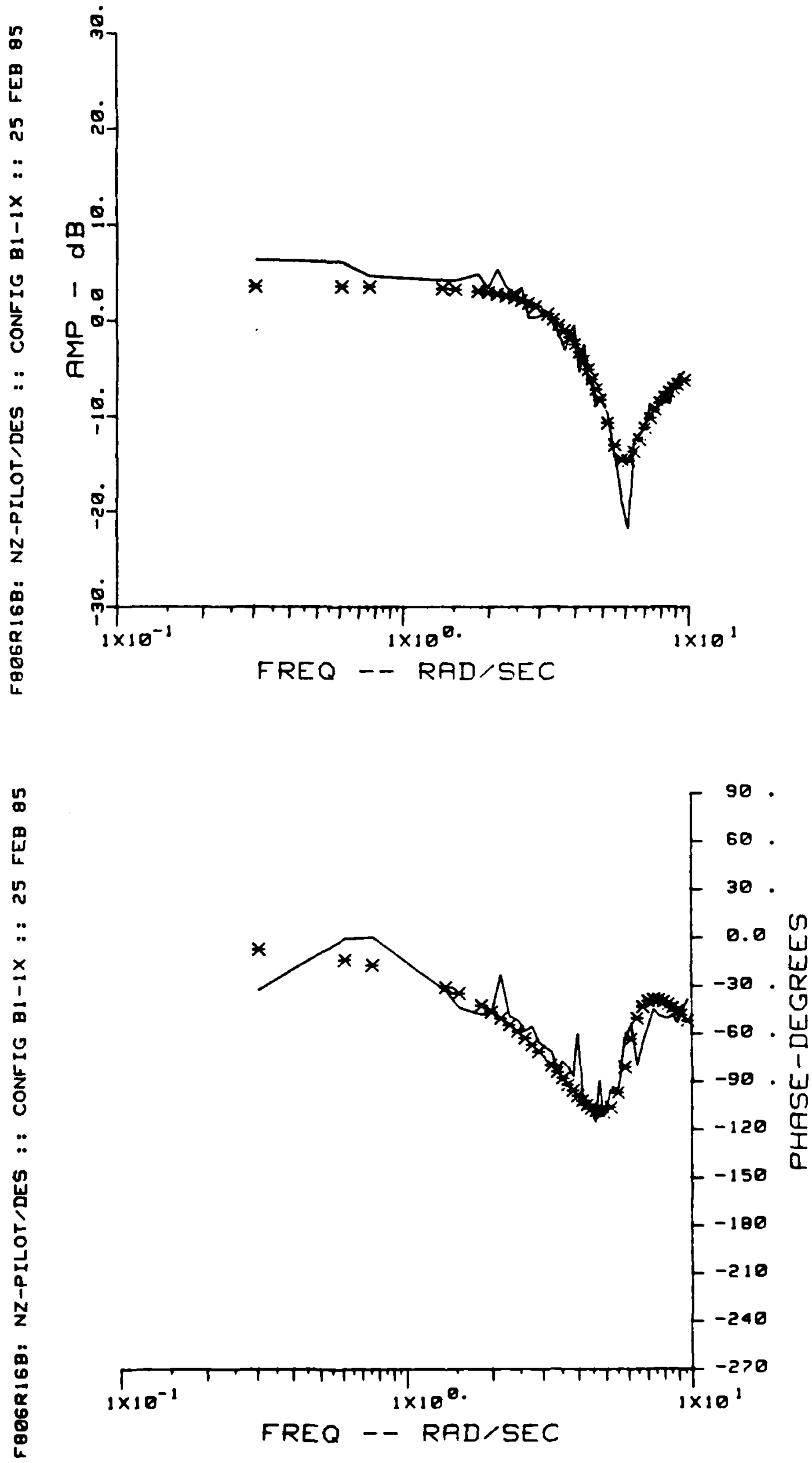


Figure D-24. (n_{z_p}/F_{es}) EQUIVALENT SYSTEM; CONFIGURATION B1-1x, FLIGHT 806, RECORD 16

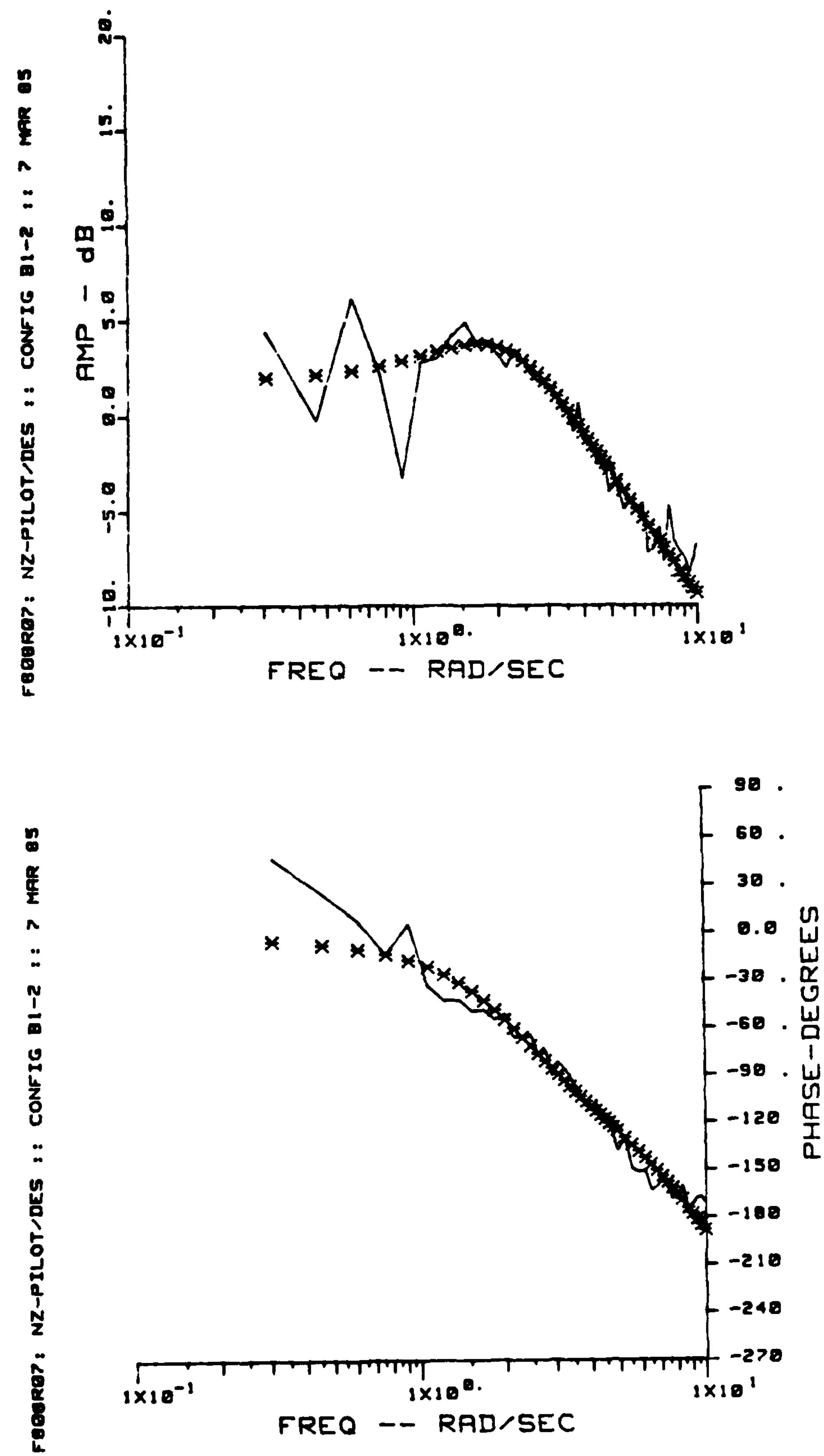
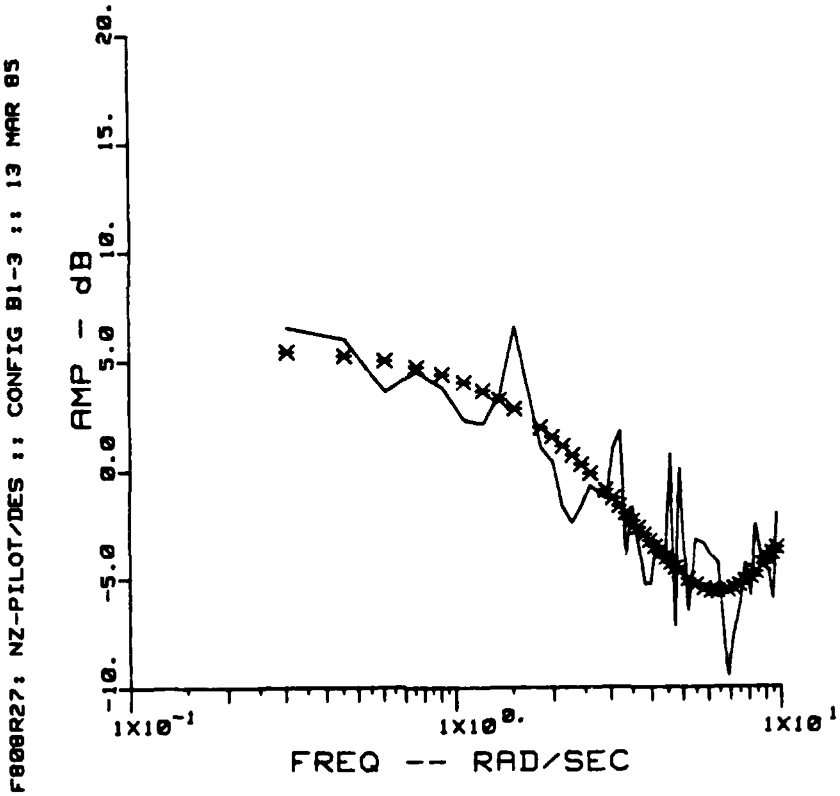


Figure D-25. (n_{z_p}/F_{es}) EQUIVALENT SYSTEM; CONFIGURATION B1-2, FLIGHT 808, RECORD 07



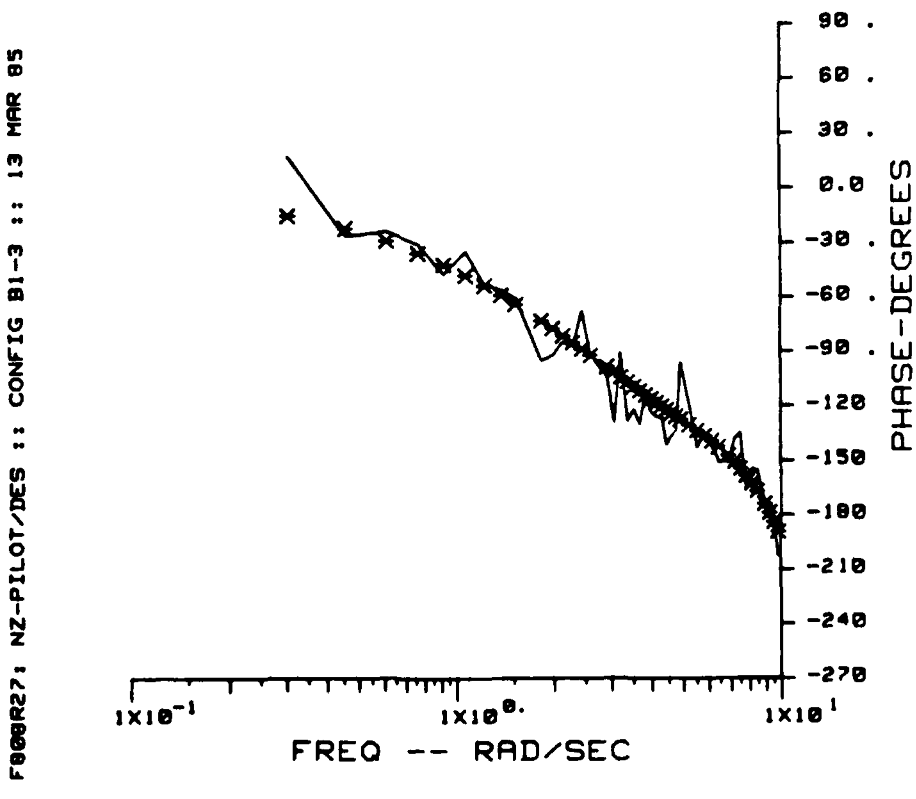


Figure D-26. (n_{z_p}/F_{es}) EQUIVALENT SYSTEM; CONFIGURATION B1-3x, FLIGHT 808, RECORD 27

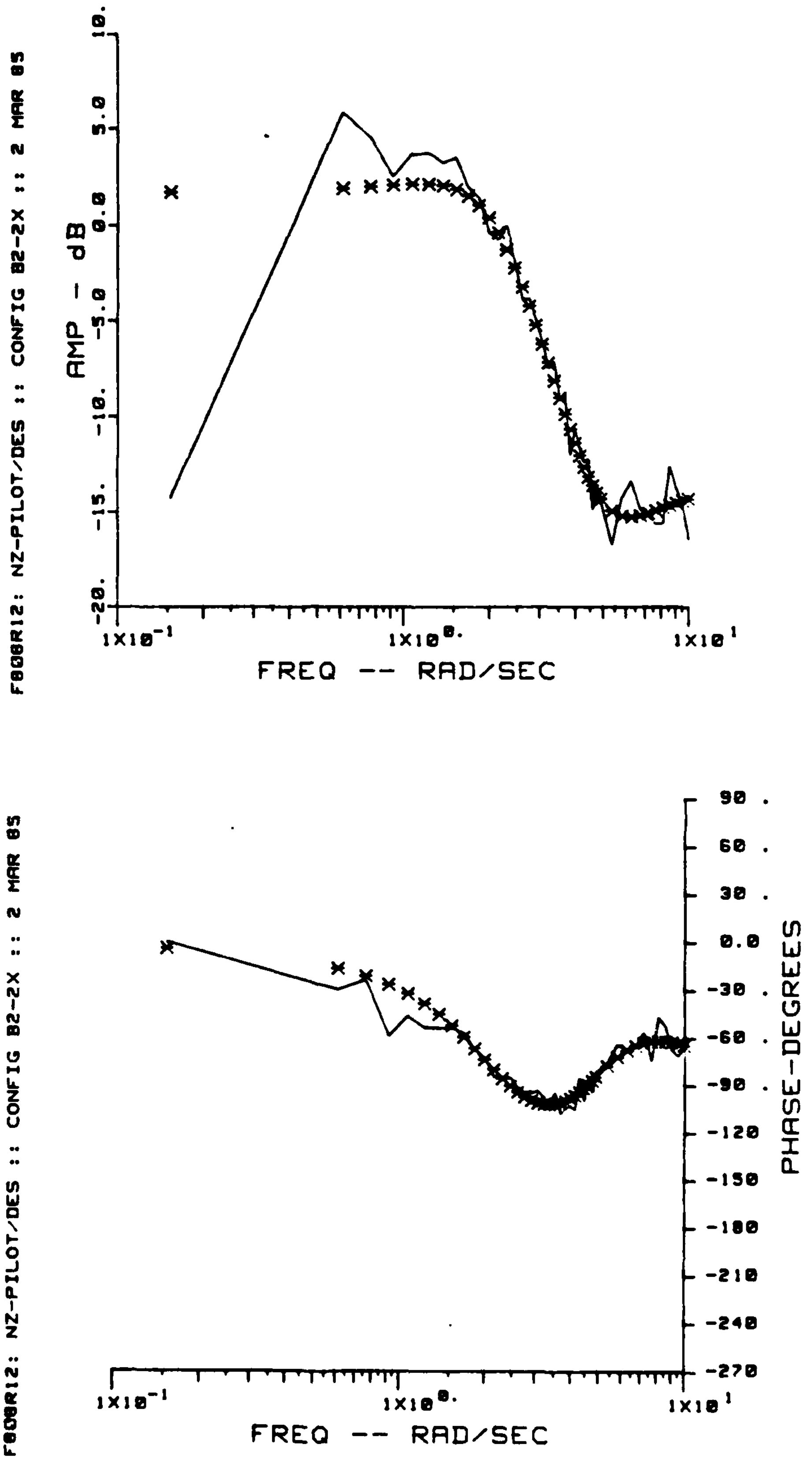
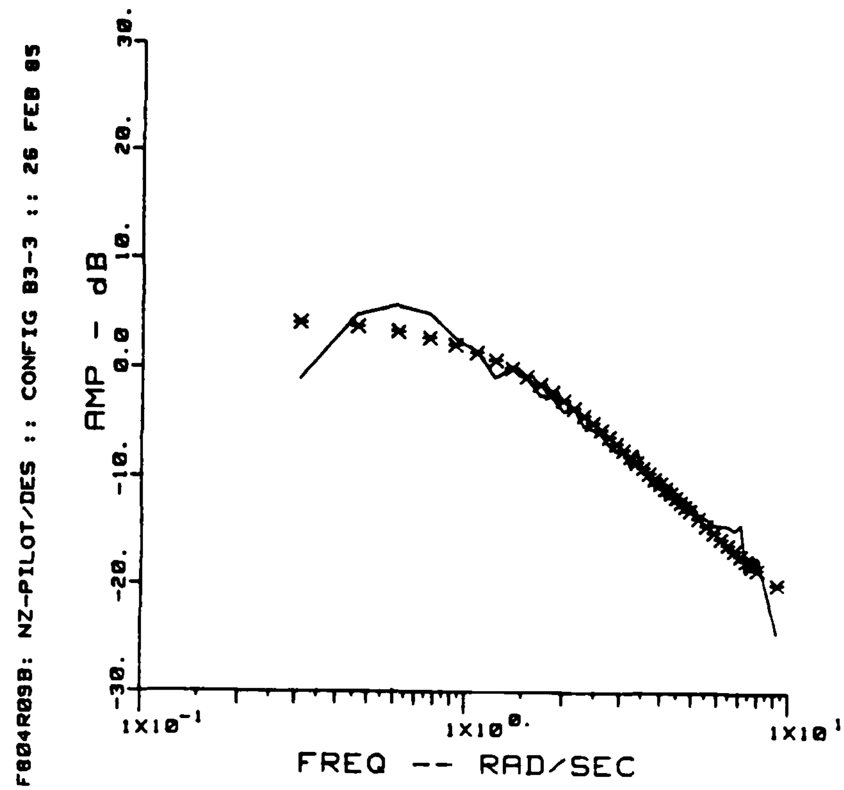


Figure D-27. (n_{z_p}/F_{es}) EQUIVALENT SYSTEM; CONFIGURATION B2-2x, FLIGHT 808, RECORD 12



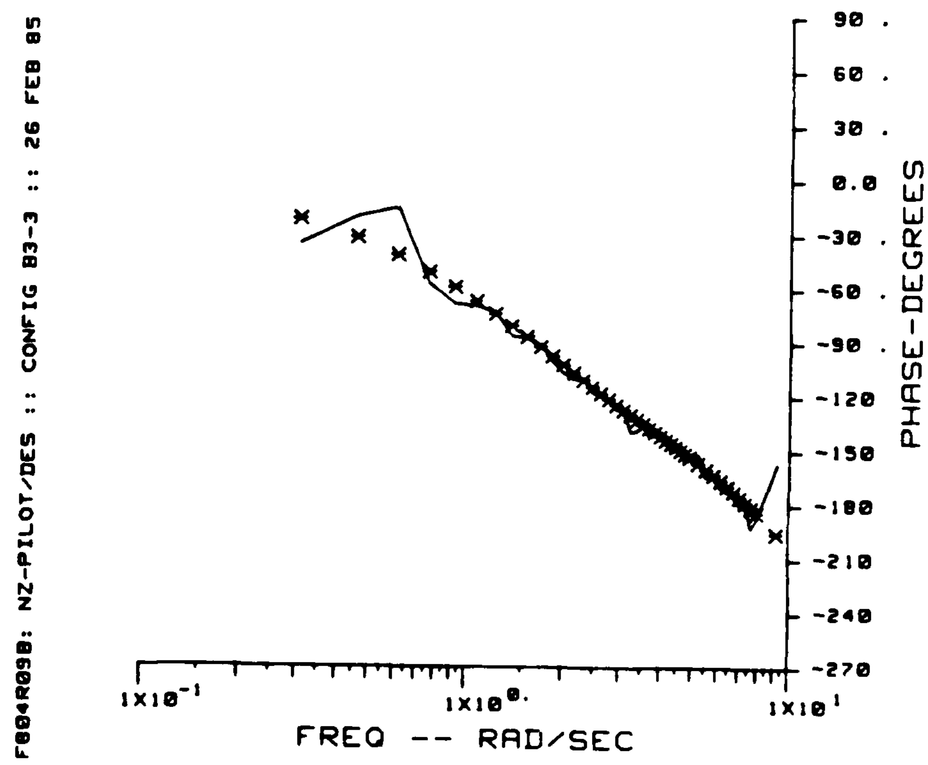
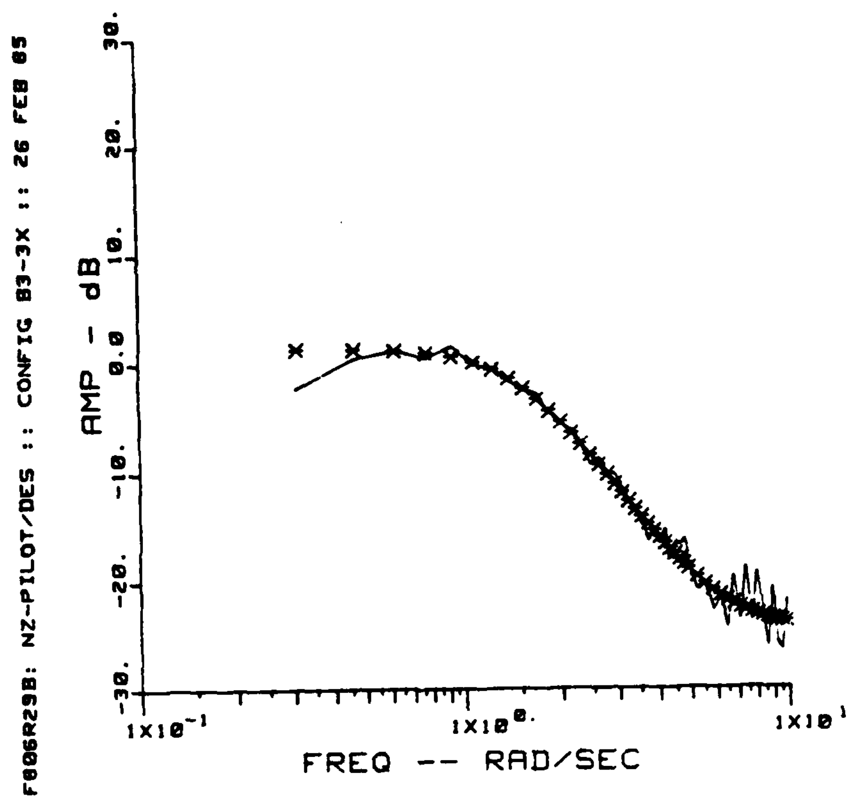


Figure D-28. (n_{z_p}/F_{es}) EQUIVALENT SYSTEM; CONFIGURATION B3-3, FLIGHT 804, RECORD 09



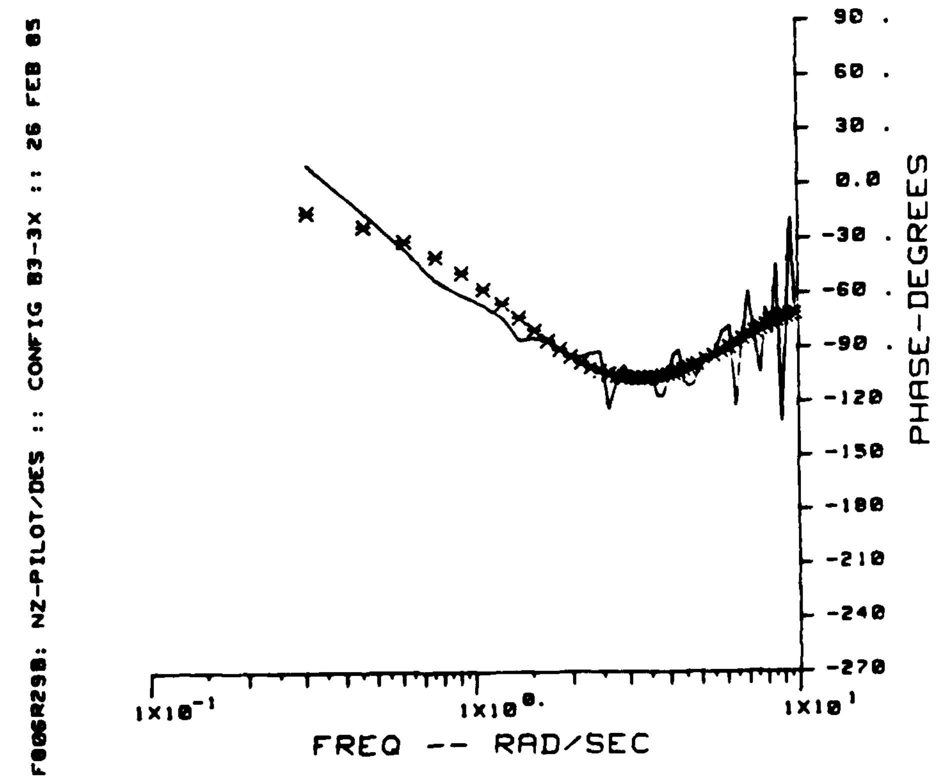
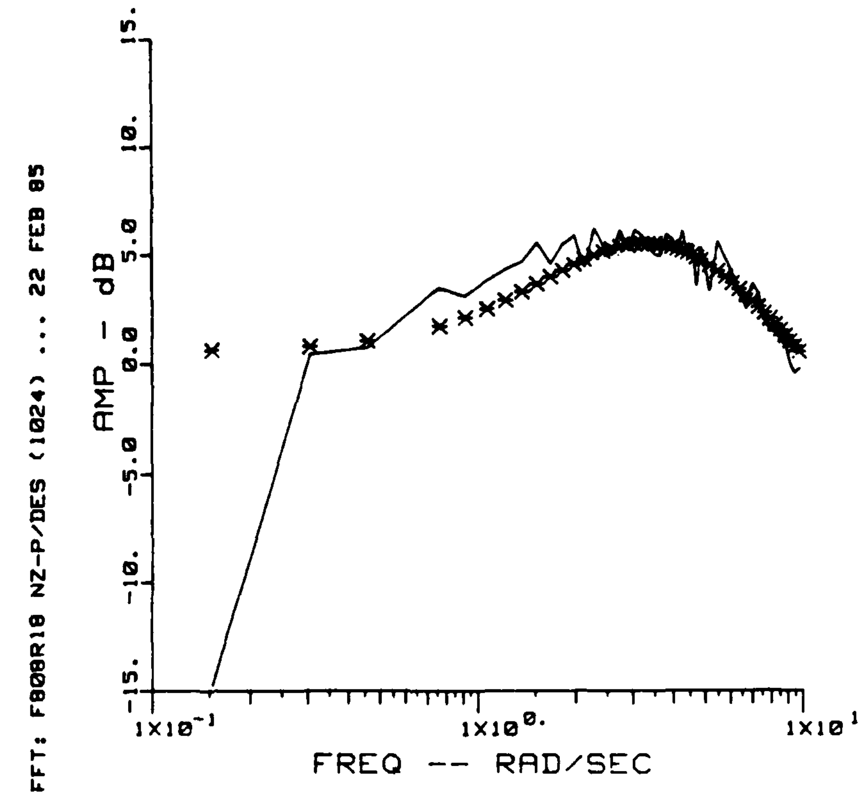


Figure D-29. (n_{z_p}/F_{es}) EQUIVALENT SYSTEM; CONFIGURATION B3-3x, FLIGHT 806, RECORD 29



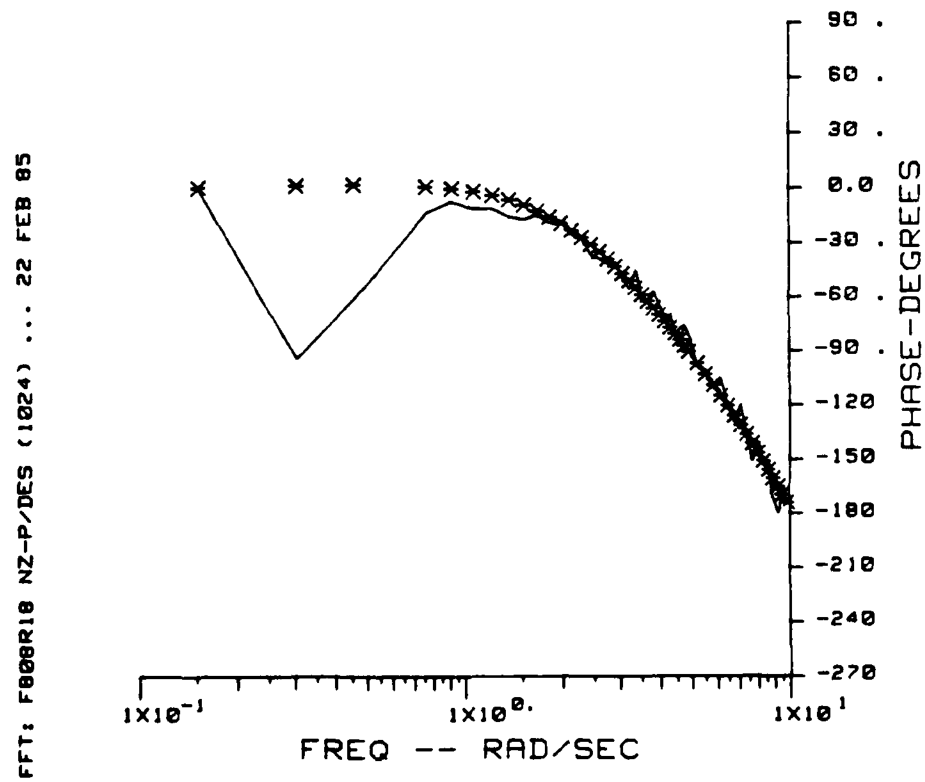


Figure D-30. (n_{z_p}/F_{es}) EQUIVALENT SYSTEM; CONFIGURATION C1-1, FLIGHT 808, RECORD 18

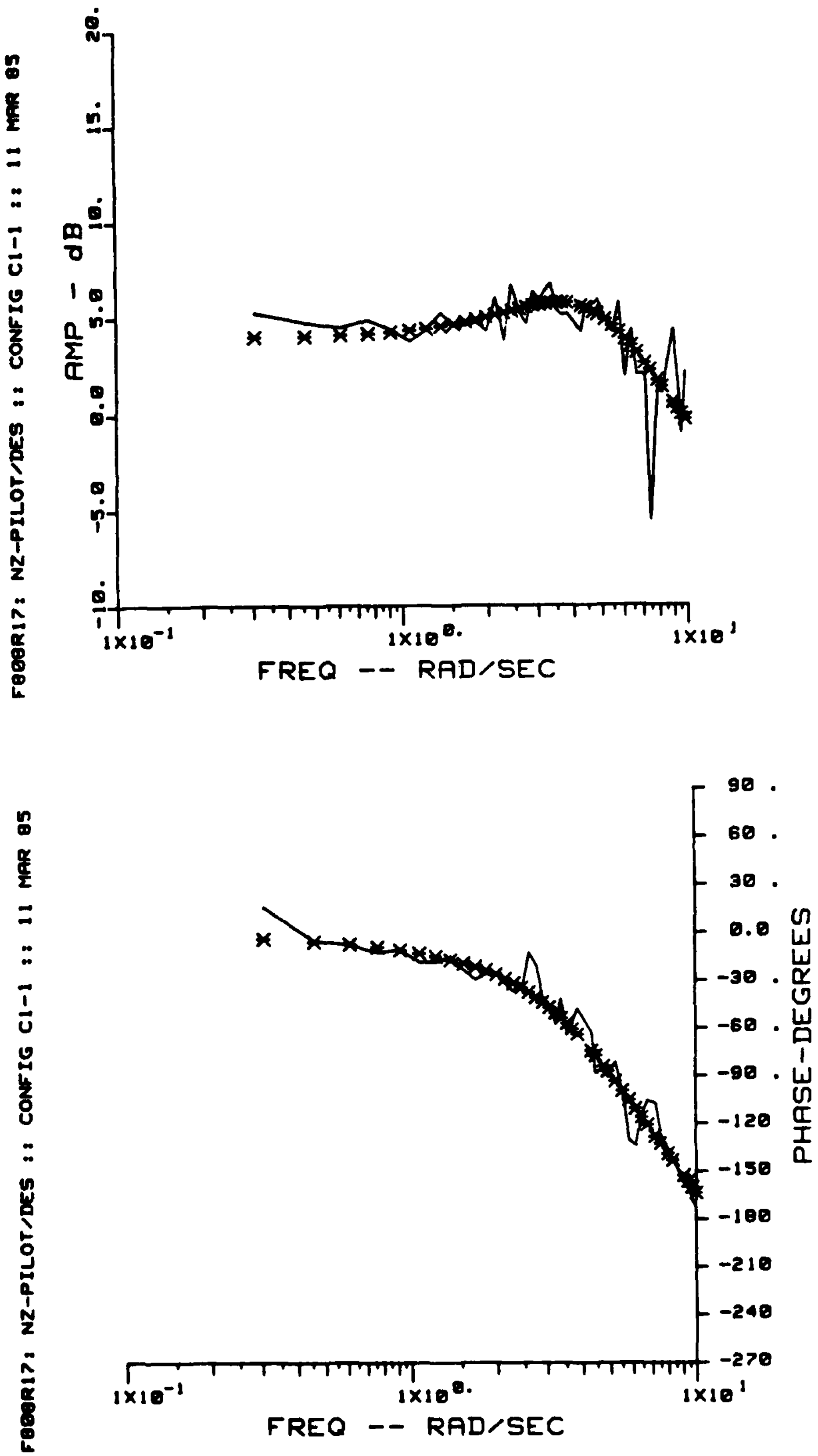


Figure D-31. (n_{z_p}/F_{es}) EQUIVALENT SYSTEM; CONFIGURATION C1-1, FLIGHT 808, RECORD 17

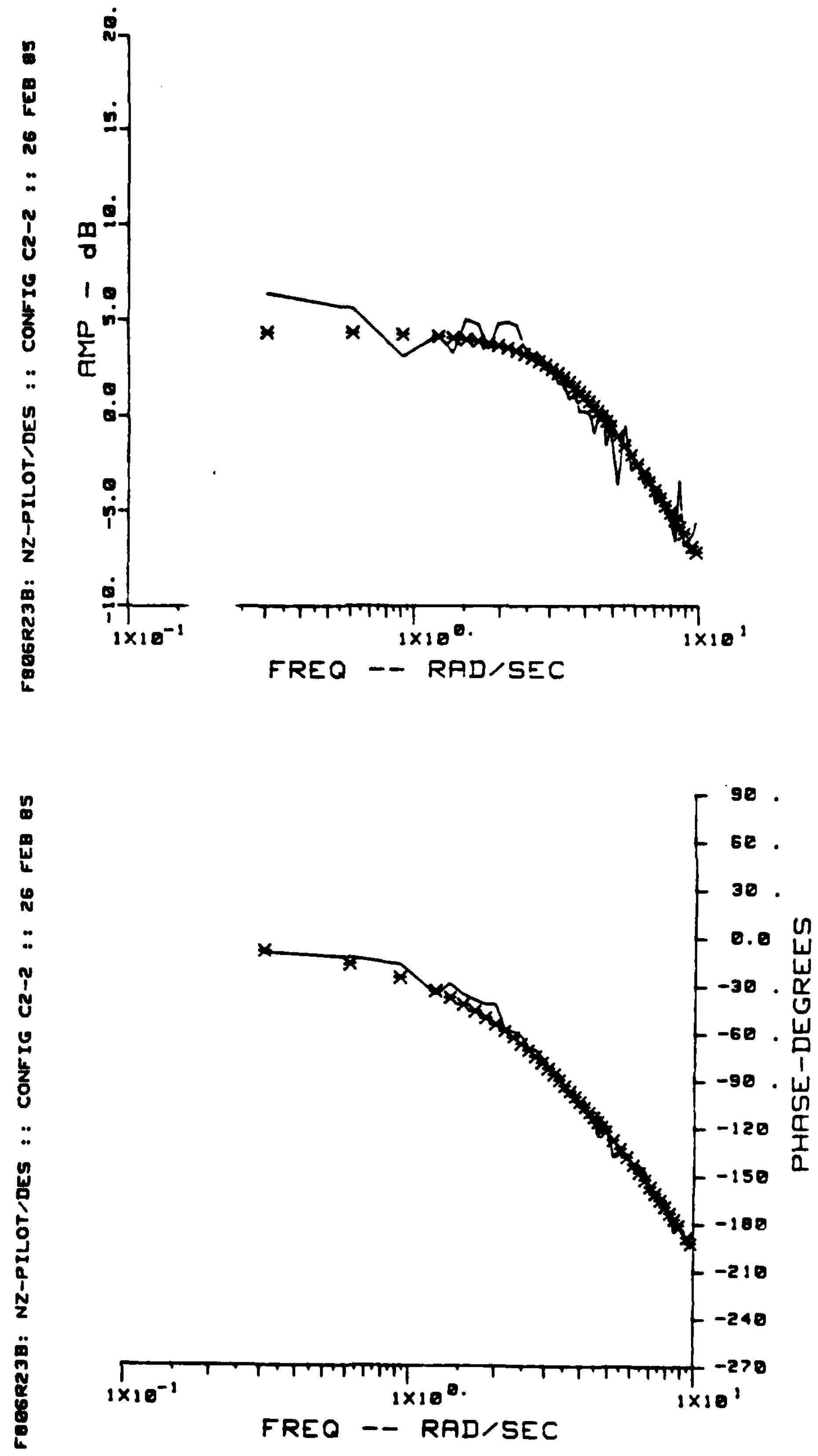
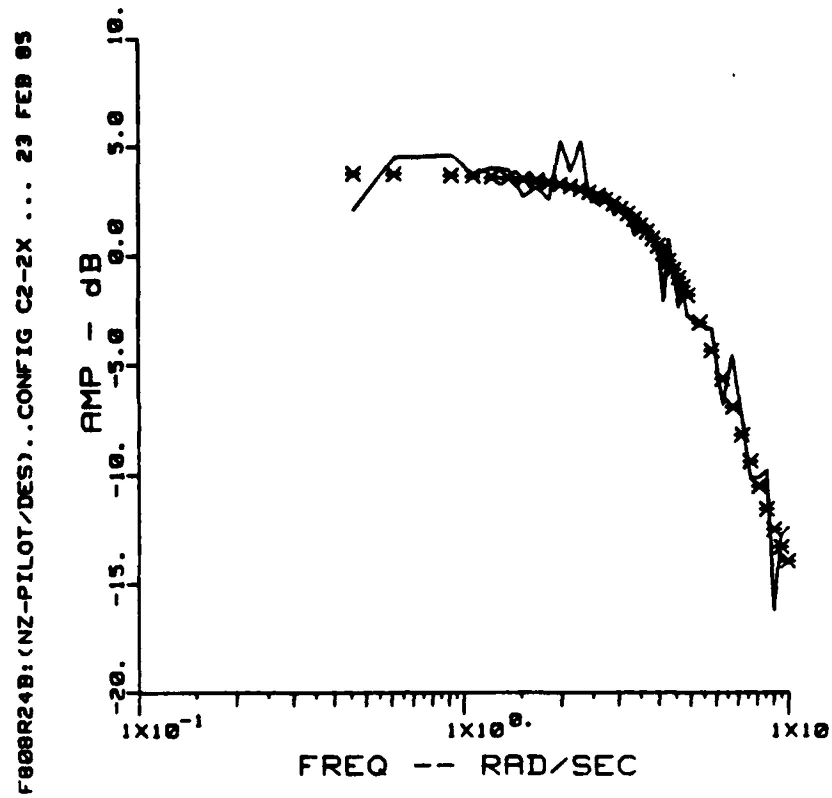


Figure D-32. (n_{z_p}/F_{es}) EQUIVALENT SYSTEM; CONFIGURATION C2-2, FLIGHT 806, RECORD 23



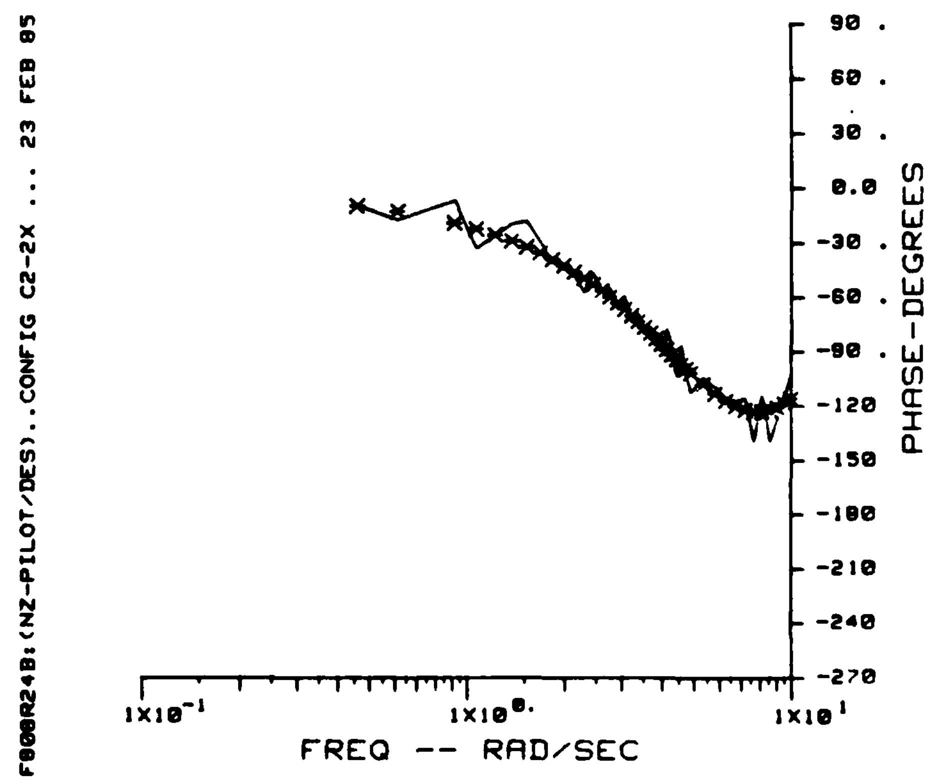
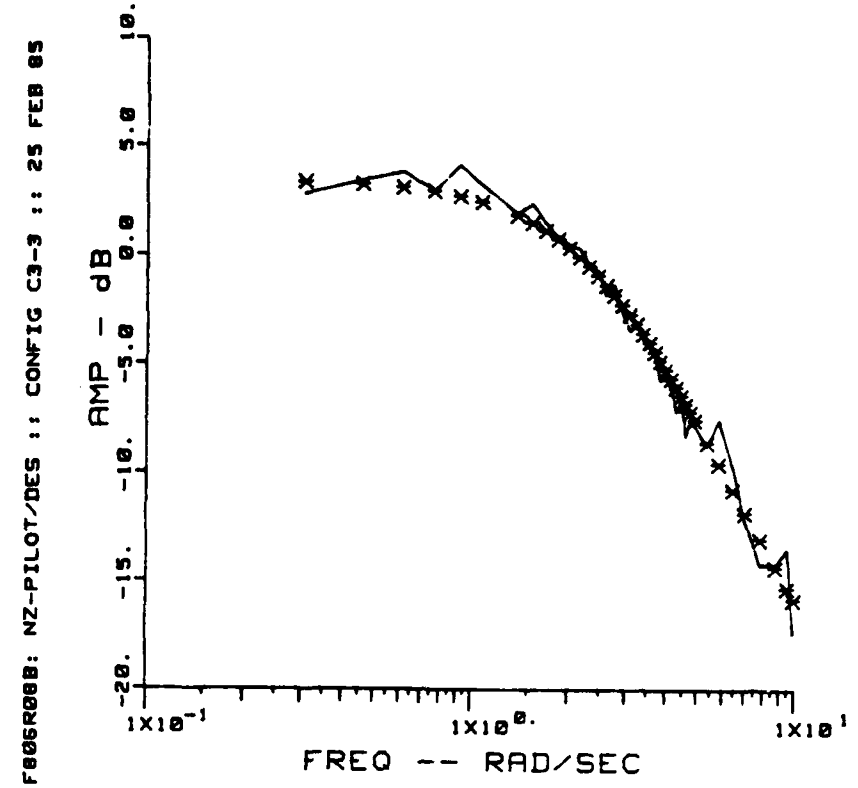


Figure D-33. (n_{z_p}/F_{es}) EQUIVALENT SYSTEM; CONFIGURATION C2-2x, FLIGHT 808, RECORD 24



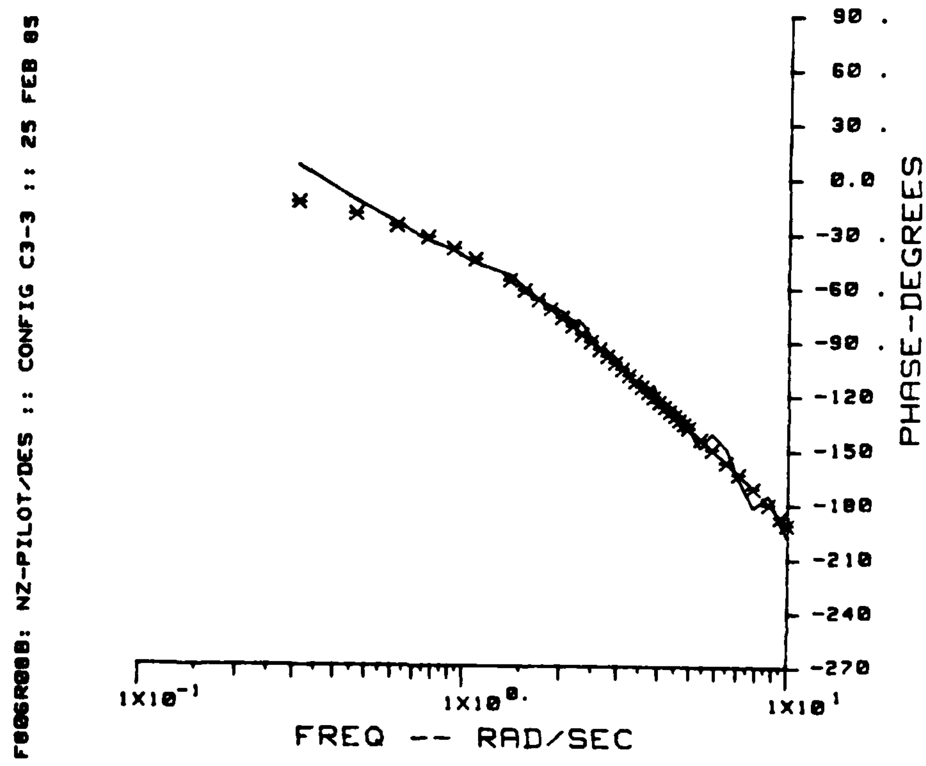


Figure D-34. (n_{z_p}/F_{es}) EQUIVALENT SYSTEM; CONFIGURATION C3-3, FLIGHT 806, RECORD 08

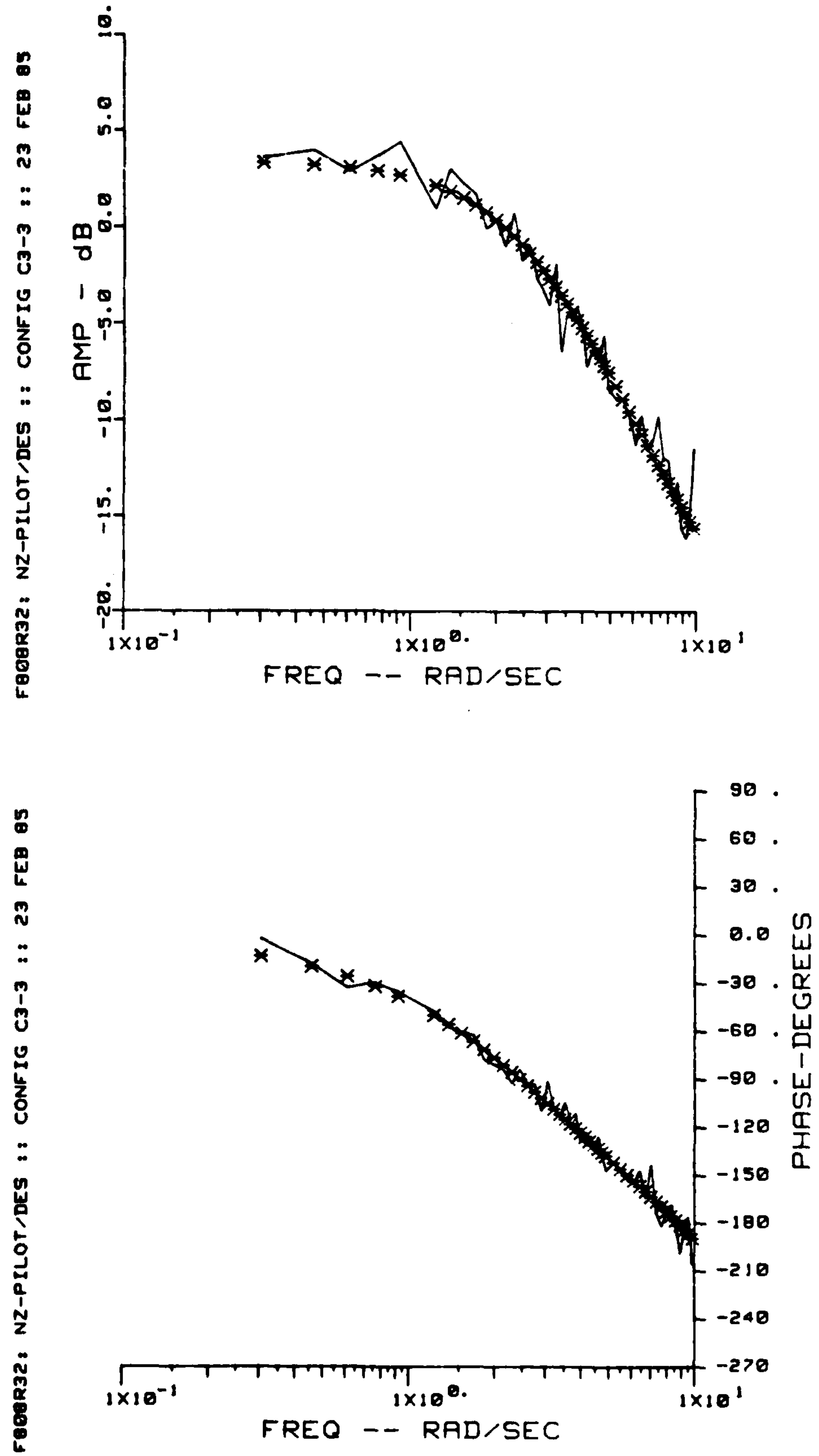
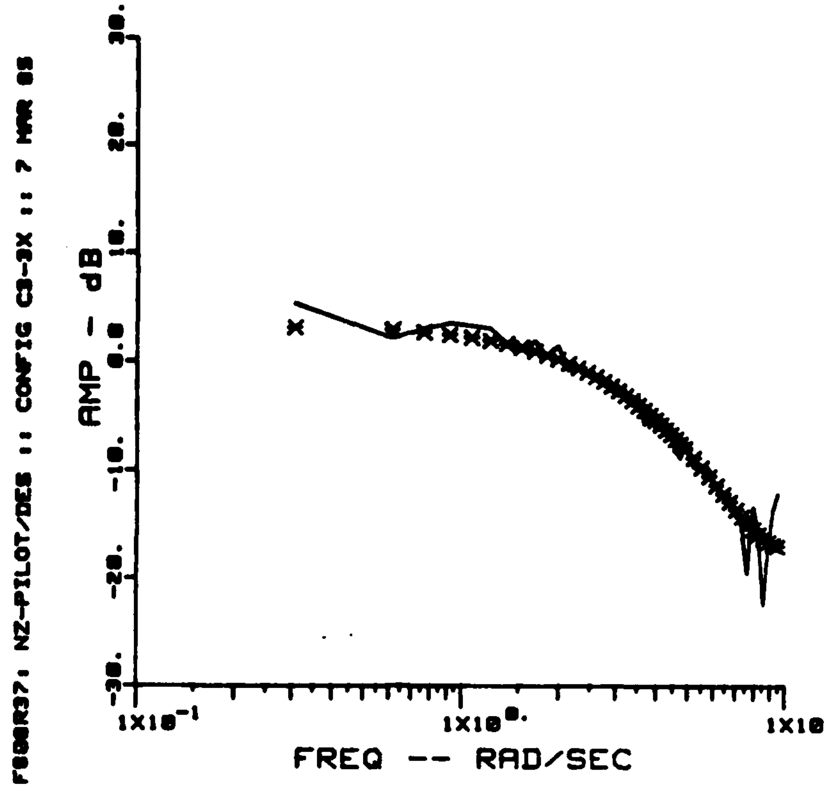


Figure D-35. (n_{z_p}/F_{es}) EQUIVALENT SYSTEM; CONFIGURATION C3-3, FLIGHT 804, RECORD 32



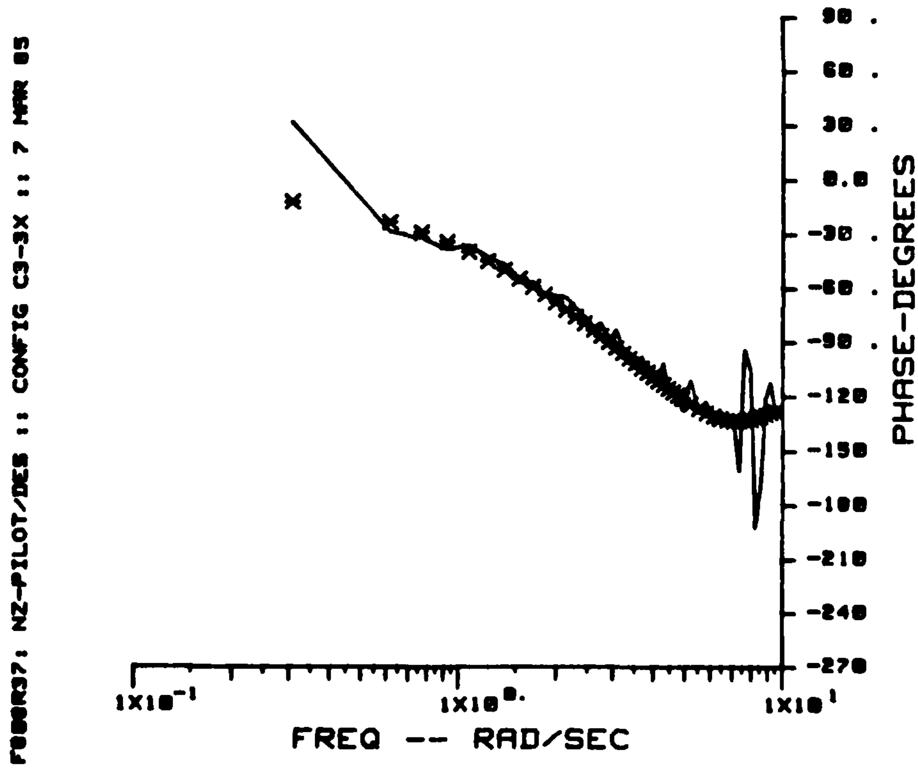
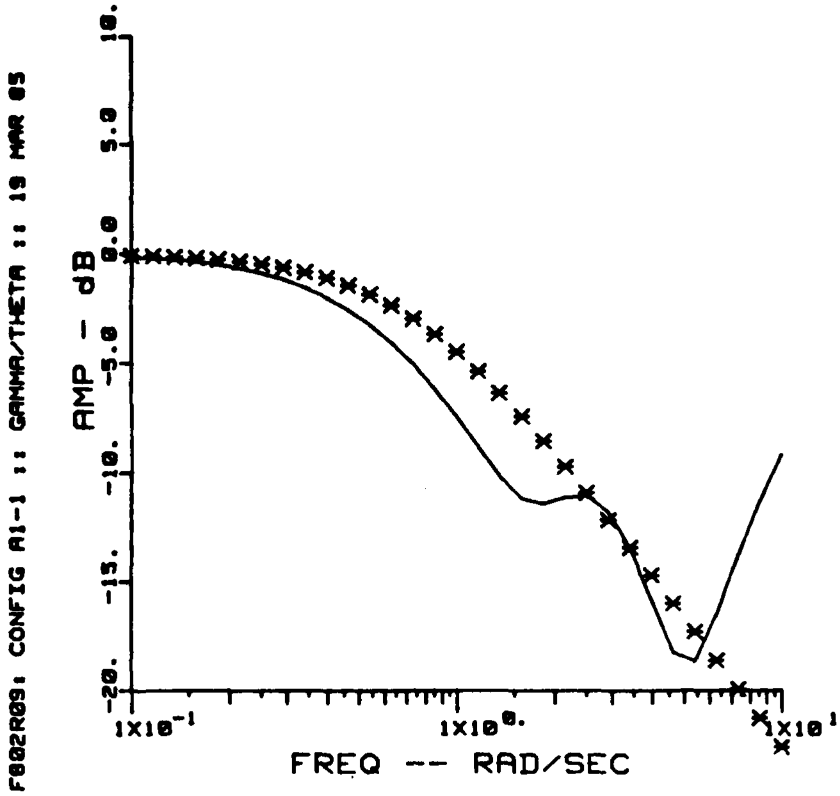


Figure D-36. (n_{z_p}/F_{es}) EQUIVALENT SYSTEM; CONFIGURATION C3-3x, FLIGHT 808, RECORD 37



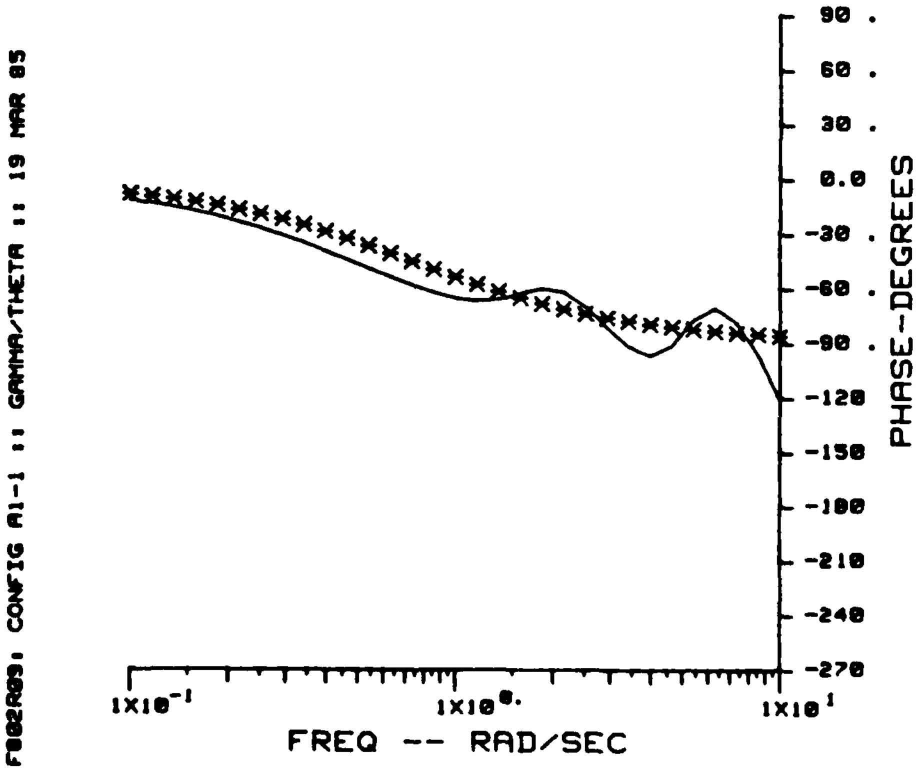


Figure D-37. ($\dot{h}_p/\theta$) EQUIVALENT SYSTEM, CONFIGURATION A1-1, FLIGHT 802, RECORD 09

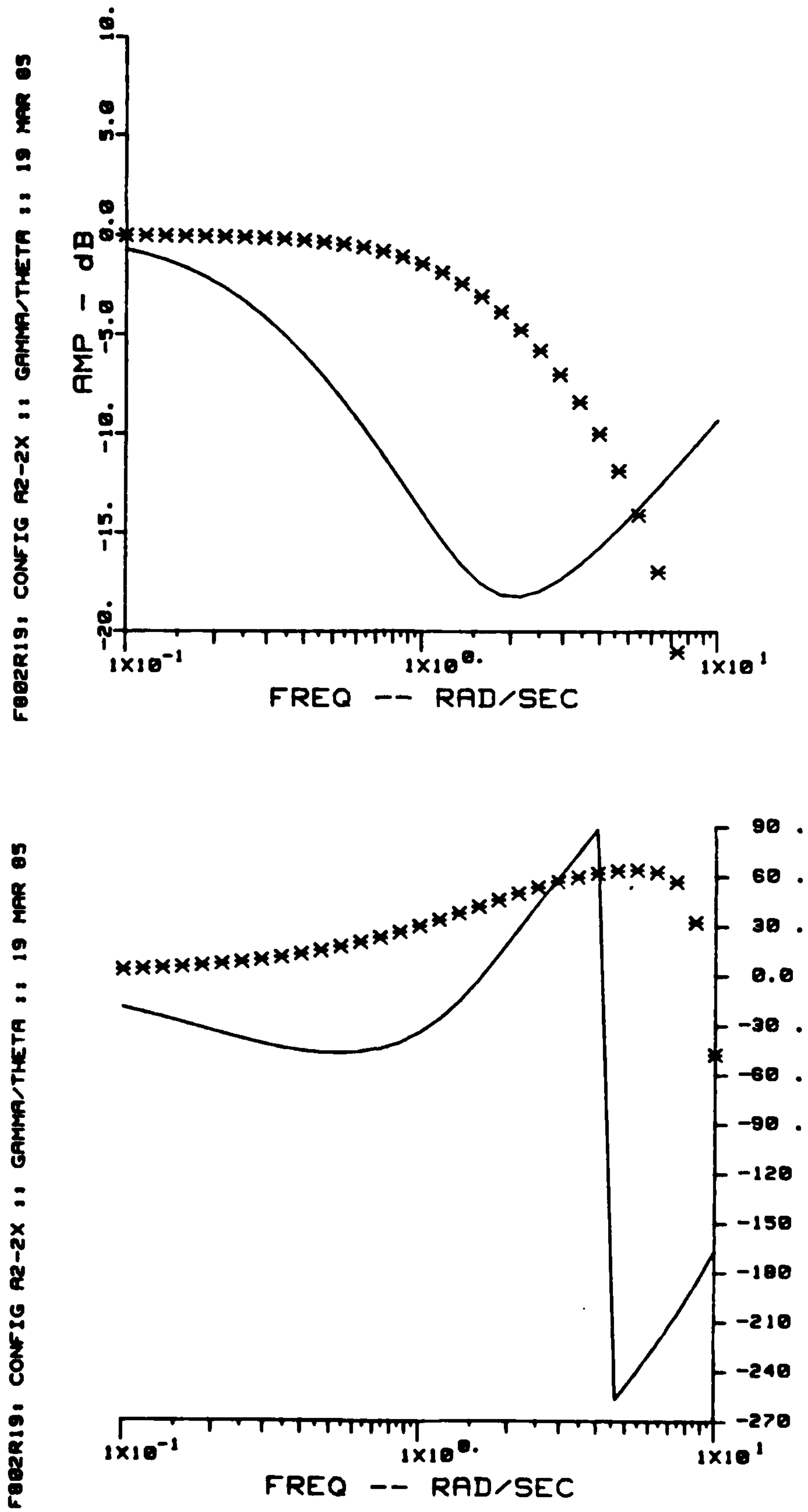
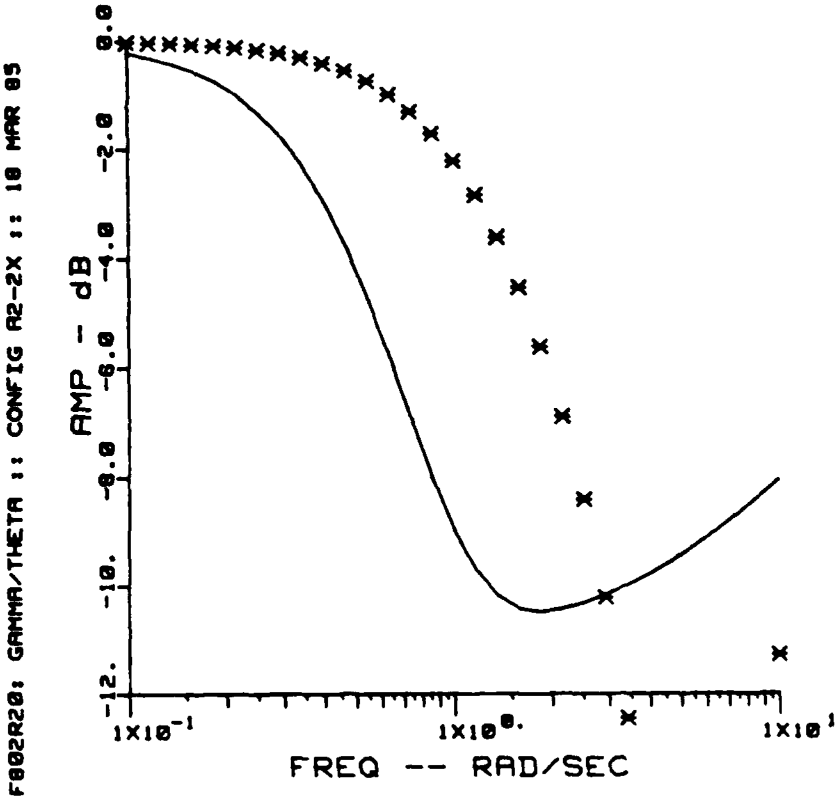


Figure D-38. ($\dot{h}_p/\theta$) EQUIVALENT SYSTEM, CONFIGURATION A2-2x, FLIGHT 802, RECORD 19



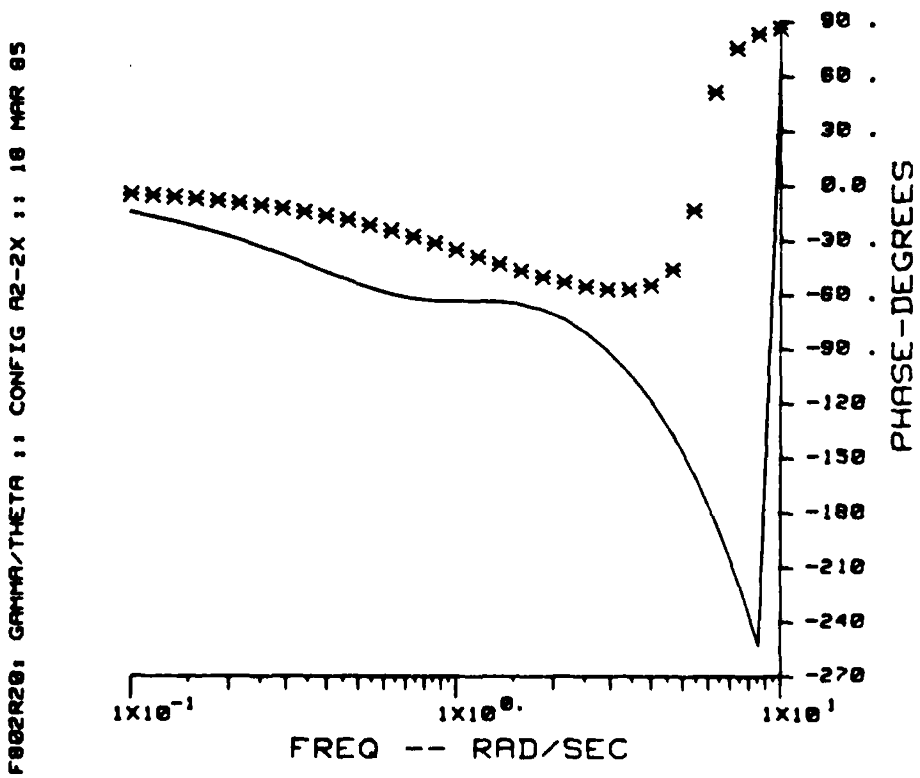
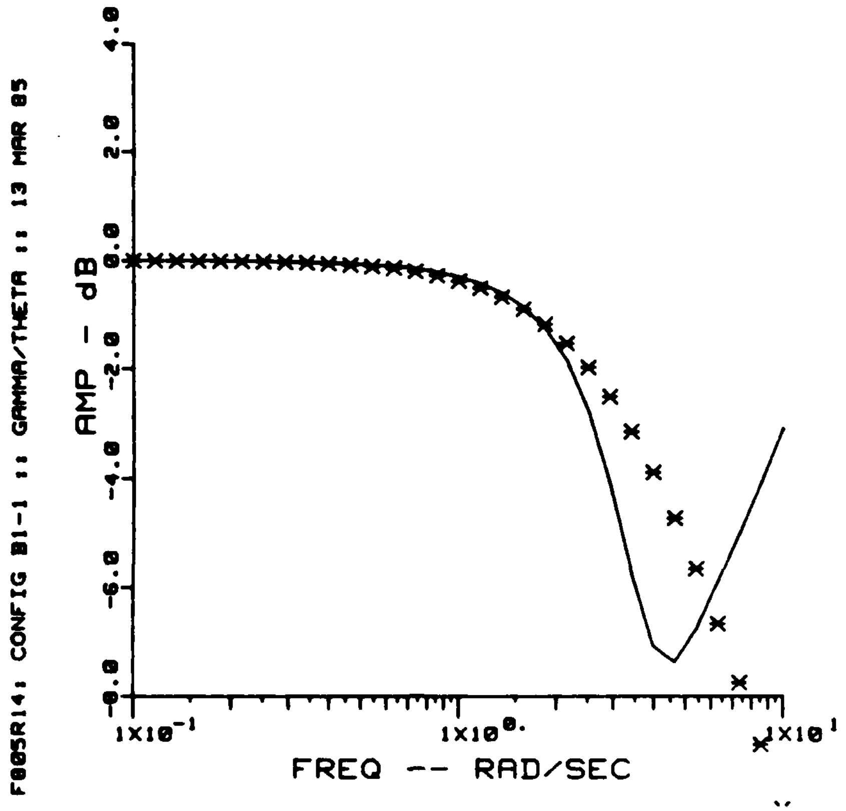


Figure D-39. ($\dot{h}_p/\theta$) EQUIVALENT SYSTEM; CONFIGURATION A2-2x, FLIGHT 802, RECORD 20



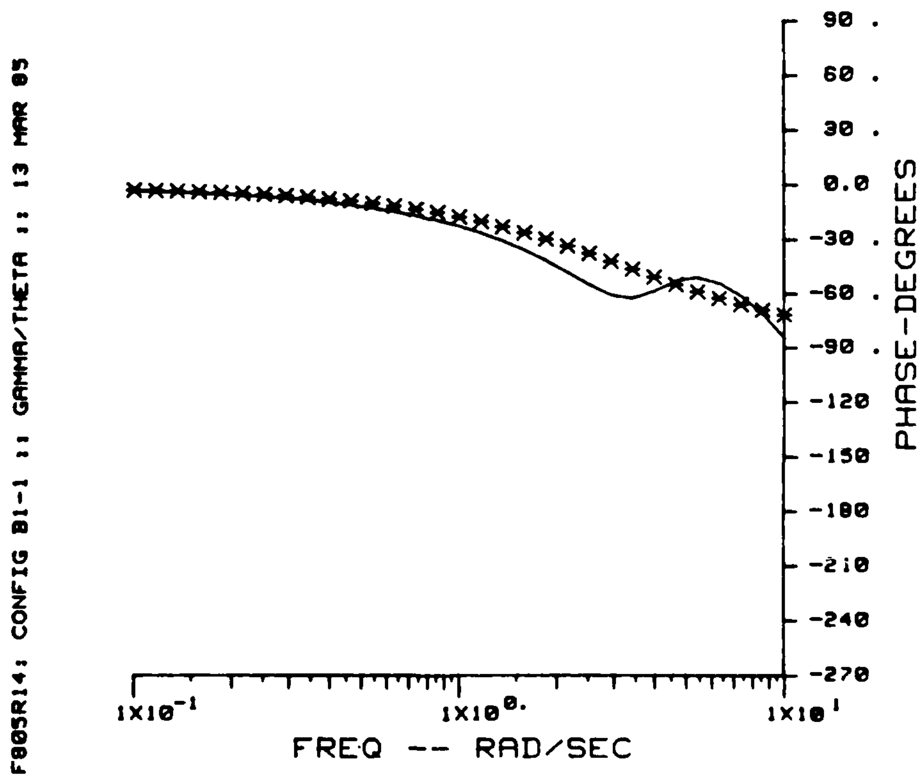


Figure D-40. ($\dot{h}_p/\theta$) EQUIVALENT SYSTEM, CONFIGURATION B1-1, FLIGHT 805, RECORD 14

AD-A181 475 EXPERIMENTAL INVESTIGATION OF THE SHORT-PERIOD REQUIREMENTS OF MIL-F-8785..(U) ARVIN/CALSPAN ADVANCED TECHNOLOGY CENTER BUFFALO NY R E BAILEY NOV 86 2/3

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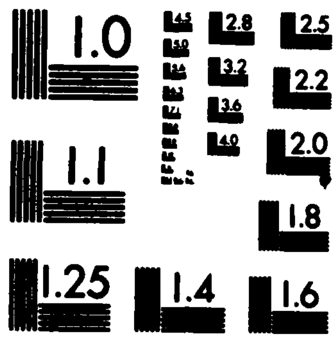
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1.1
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1.4
1.6
1.8
2.0
2.2
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2.8
3.2
3.6
4.0

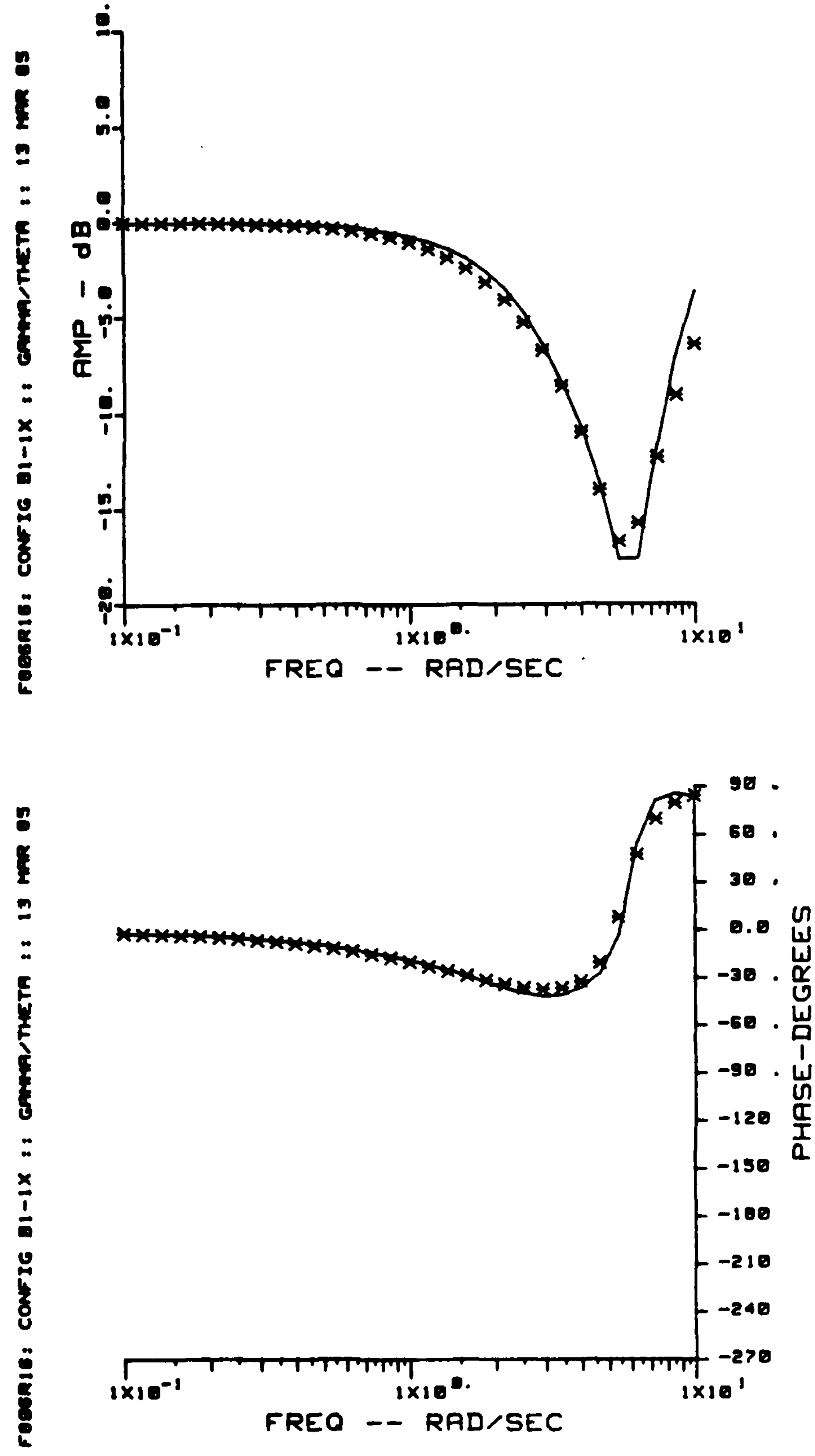
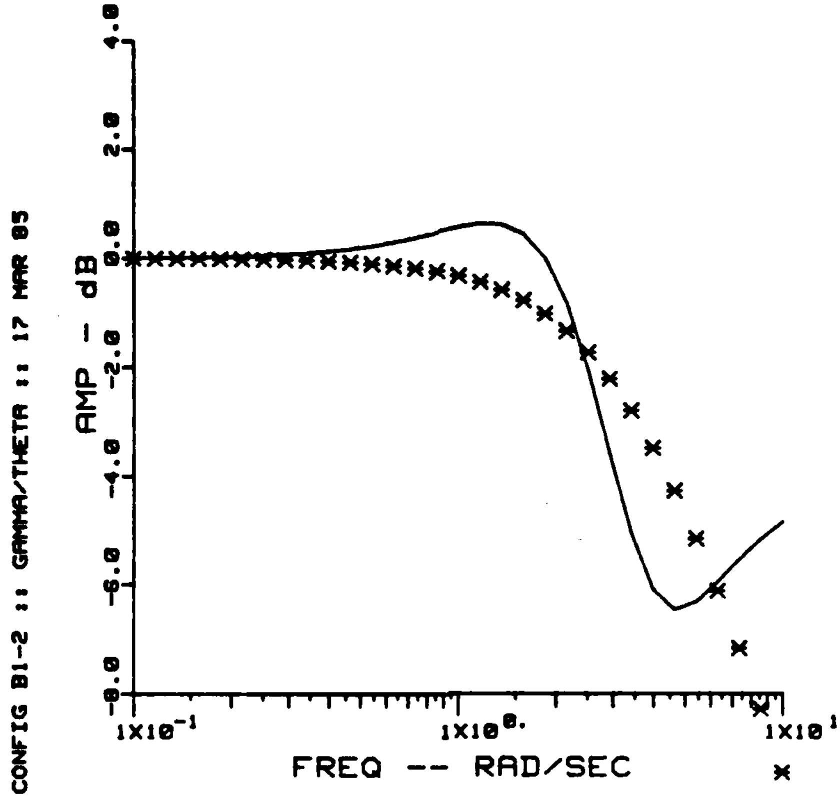


Figure D-41. $(\dot{h}_p/\theta)$ EQUIVALENT SYSTEM, CONFIGURATION B1-1x, FLIGHT 806, RECORD 16



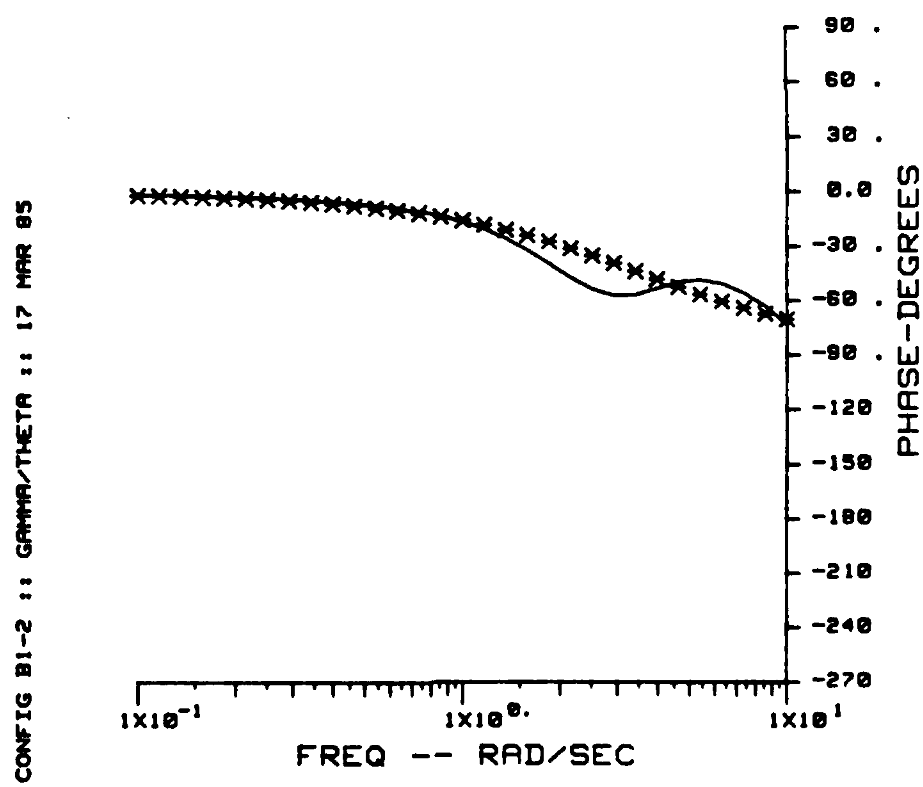
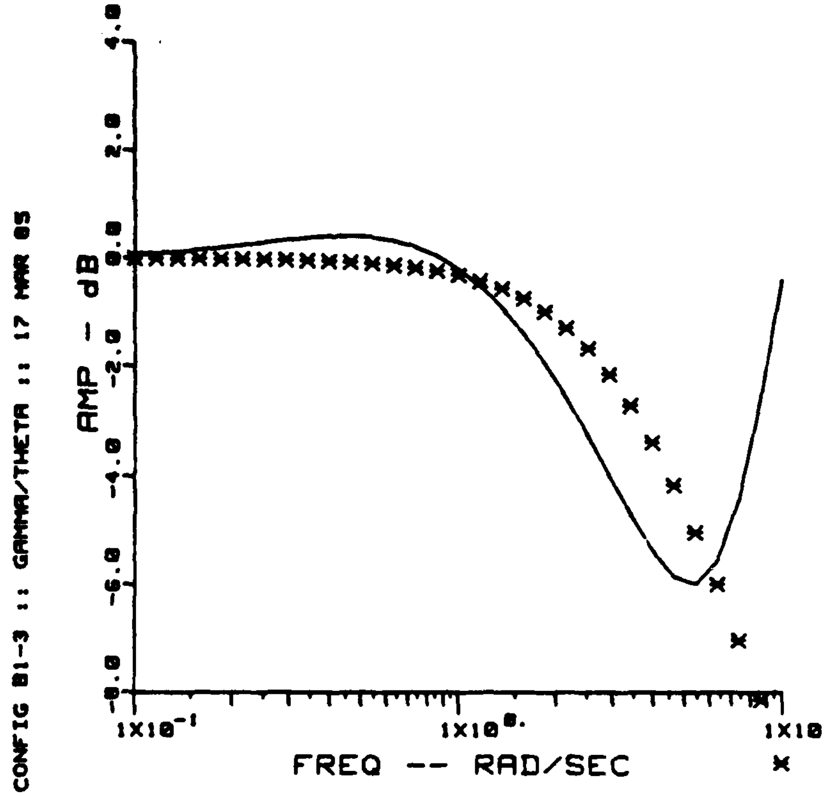


Figure D-42. ($\dot{h}_p/\theta$) EQUIVALENT SYSTEM; CONFIGURATION B1-2, FLIGHT 808, RECORD 07



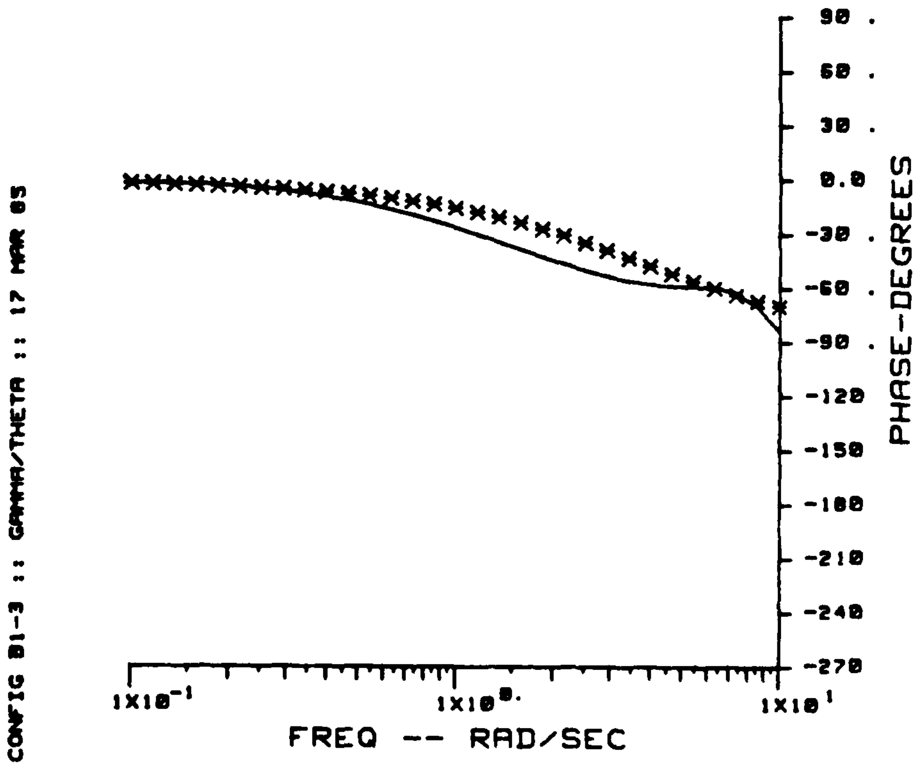


Figure D-43. ($\dot{h}_p/e$) EQUIVALENT SYSTEM, CONFIGURATION B1-3, FLIGHT 808, RECORD 27

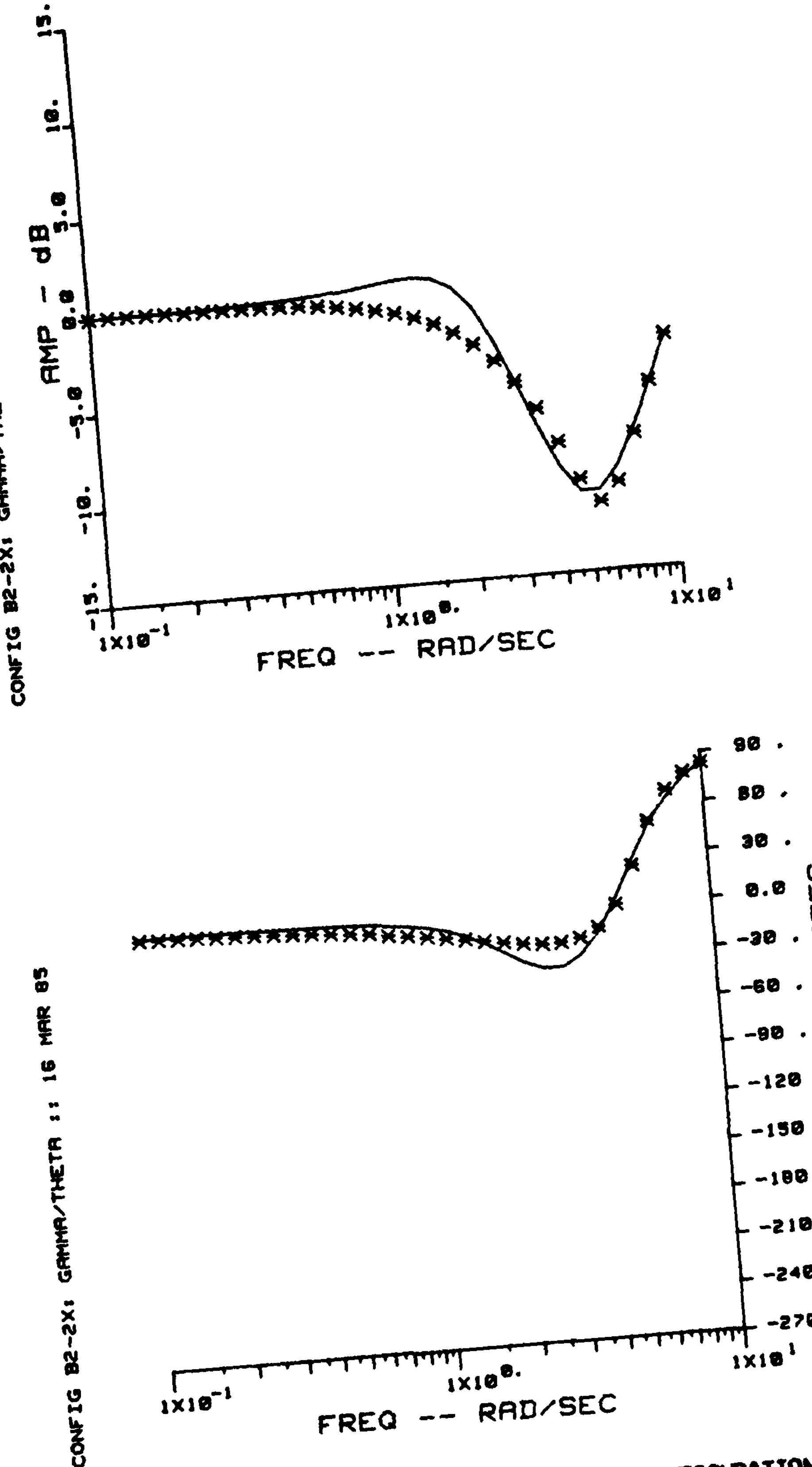
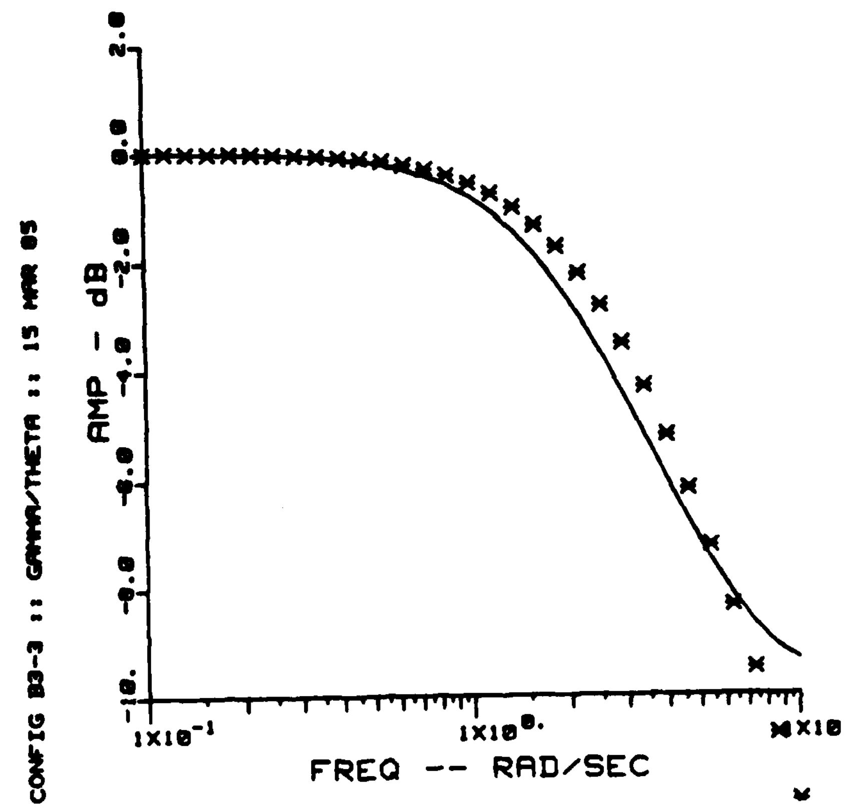


Figure D-4A. ($\dot{h}_p/e$) EQUIVALENT SYSTEM, CONFIGURATION B2-2x, FLIGHT 808, RECORD 12



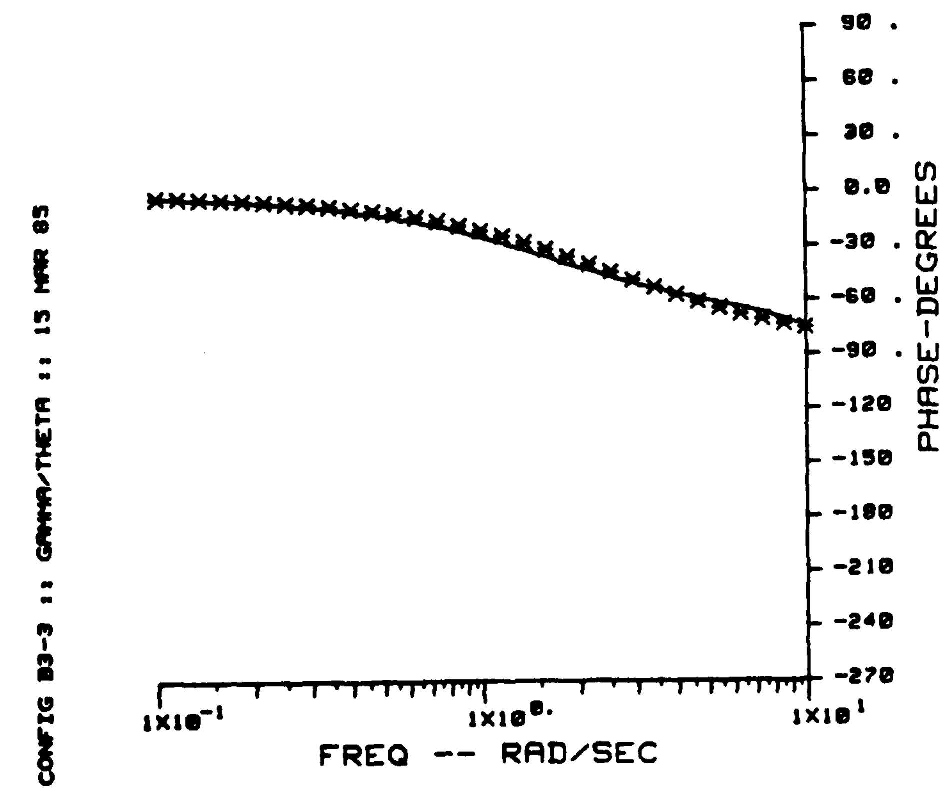
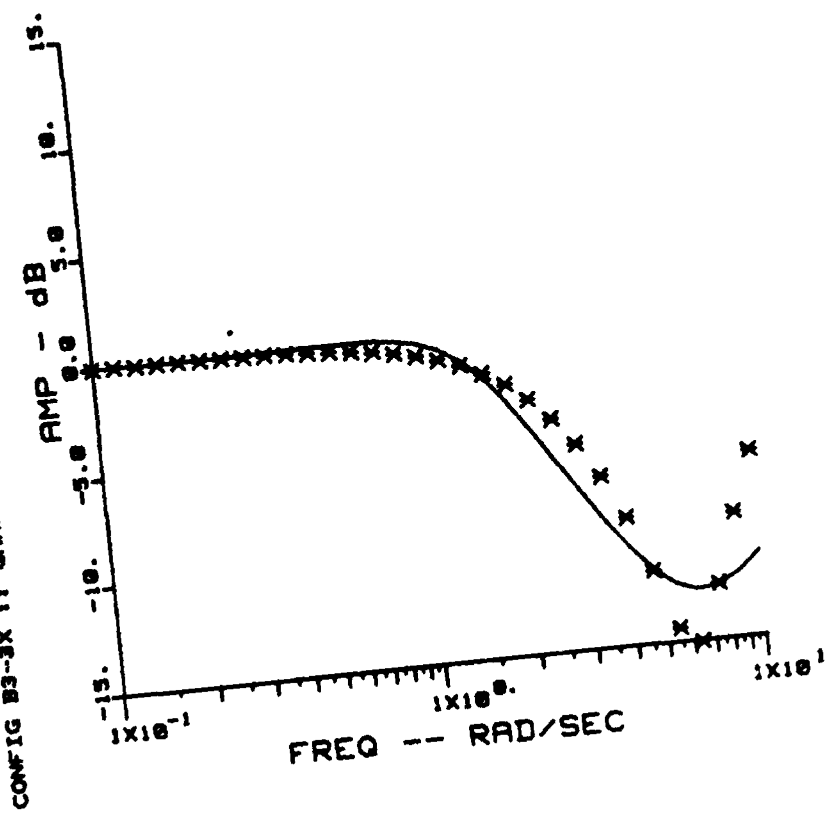


Figure D-45. ($\dot{h}_p/\theta$) EQUIVALENT SYSTEM, CONFIGURATION B3-3, FLIGHT 804, RECORD 09



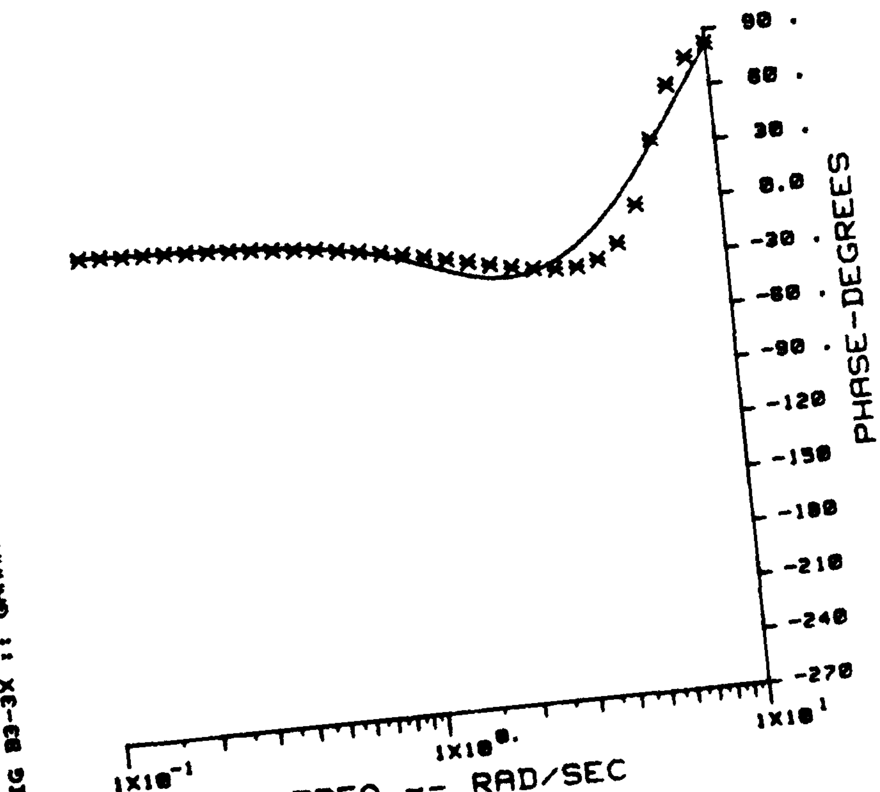


Figure D-46. ($\dot{h}_p/\theta$) EQUIVALENT SYSTEM, CONFIGURATION B3-3x, FLIGHT 806, RECORD 29

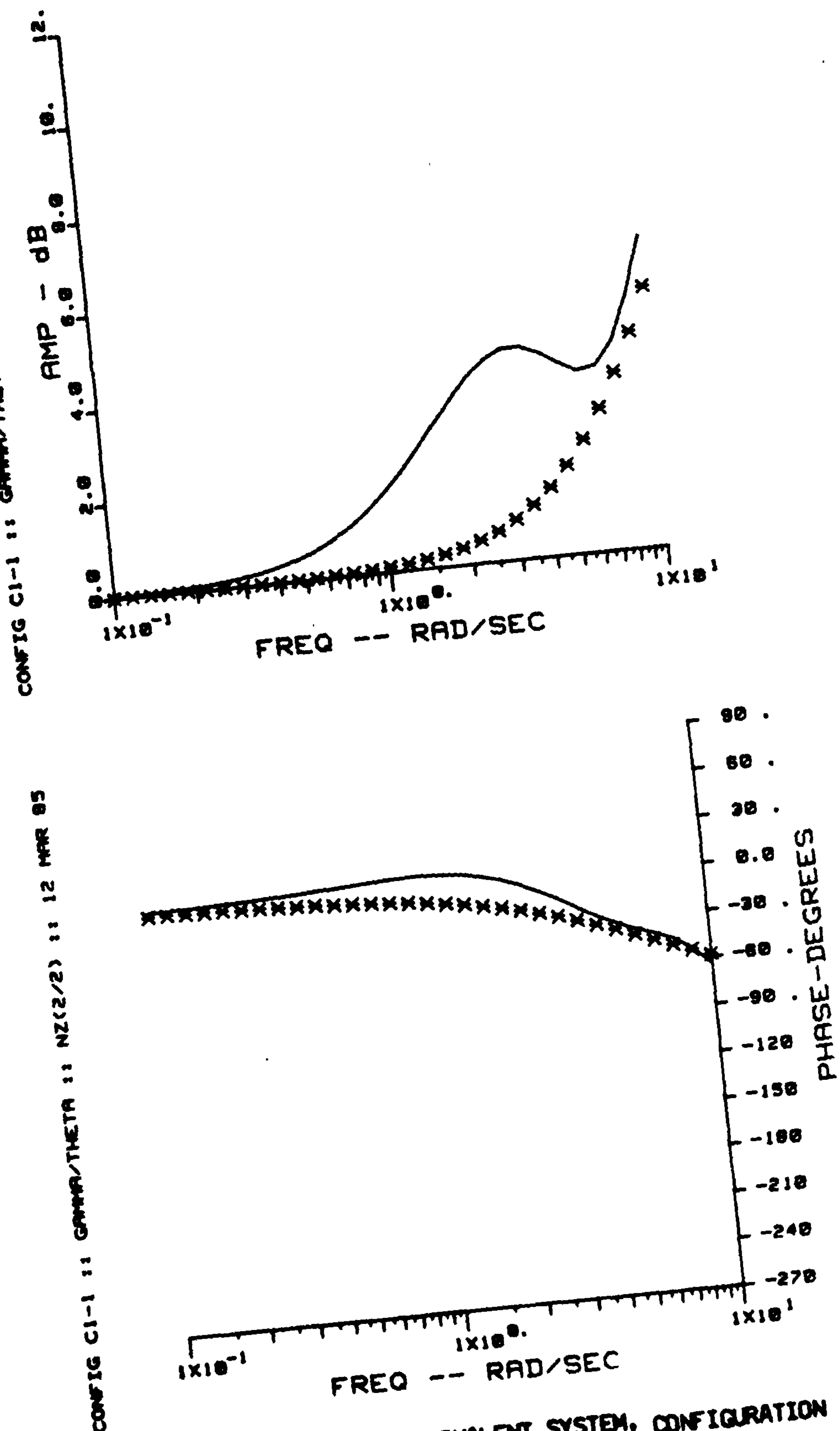
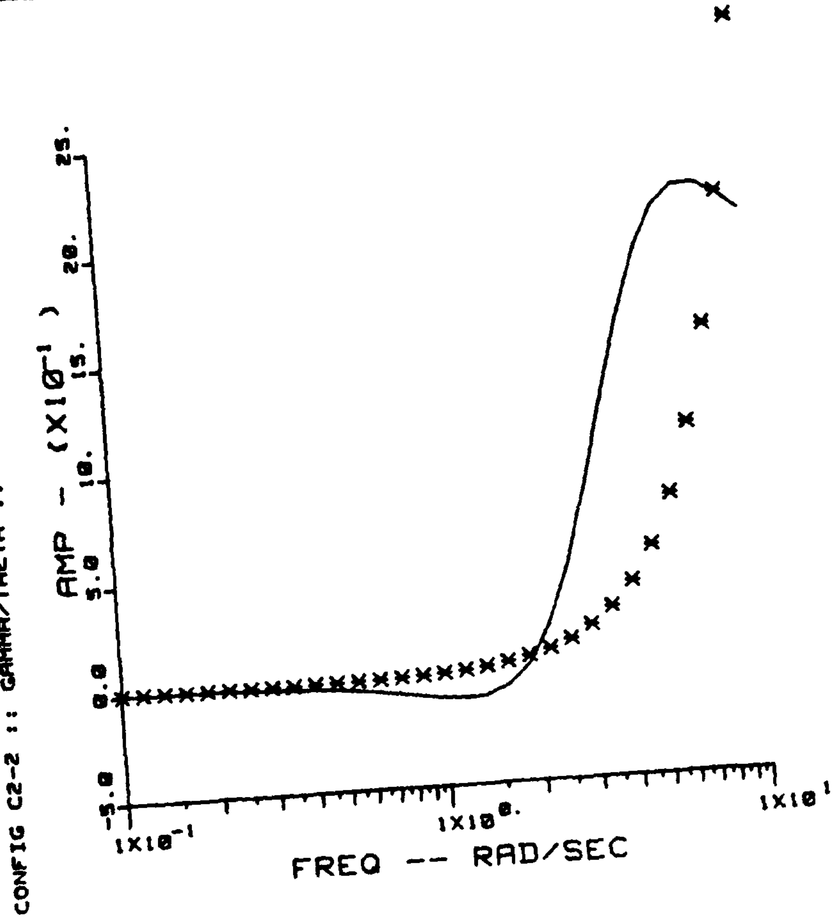


Figure D-47. ($\dot{h}_p/e$) EQUIVALENT SYSTEM, CONFIGURATION C1-1, FLIGHT 808, RECORD 18



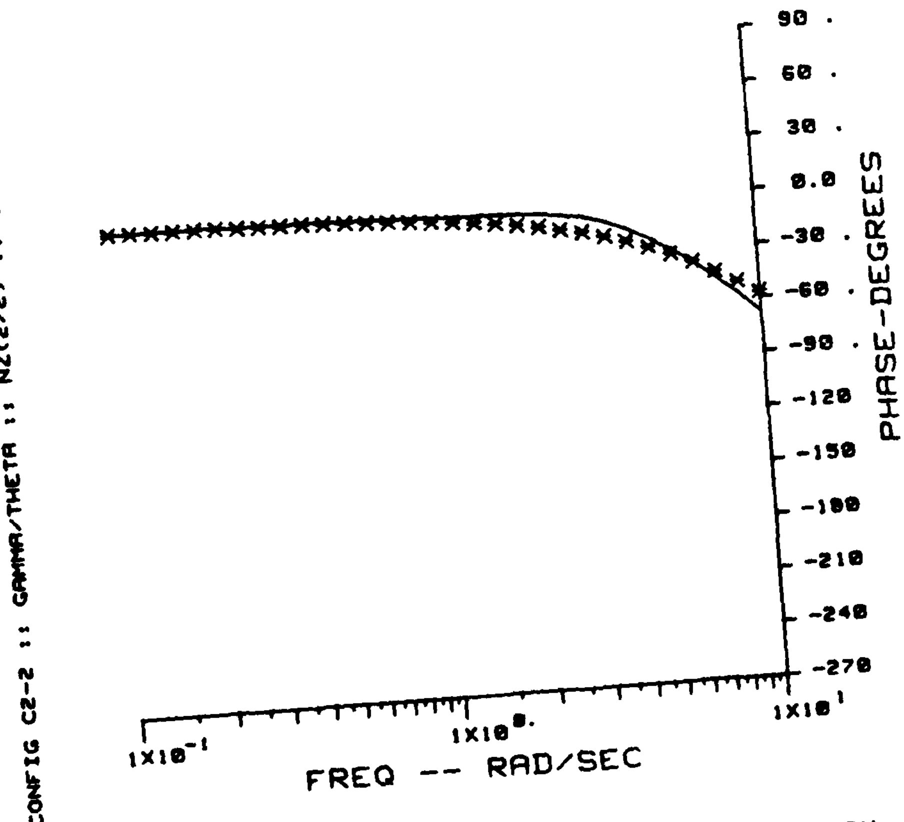
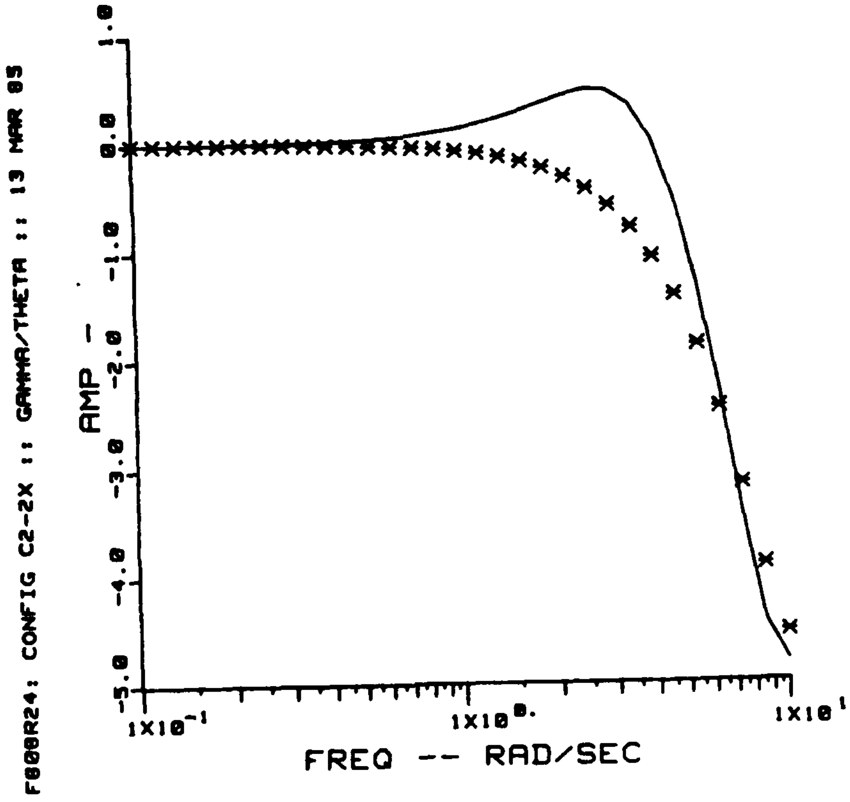


Figure D-48. ($\dot{h}_p/\theta$) EQUIVALENT SYSTEM, CONFIGURATION C2-2, FLIGHT 806, RECORD 23



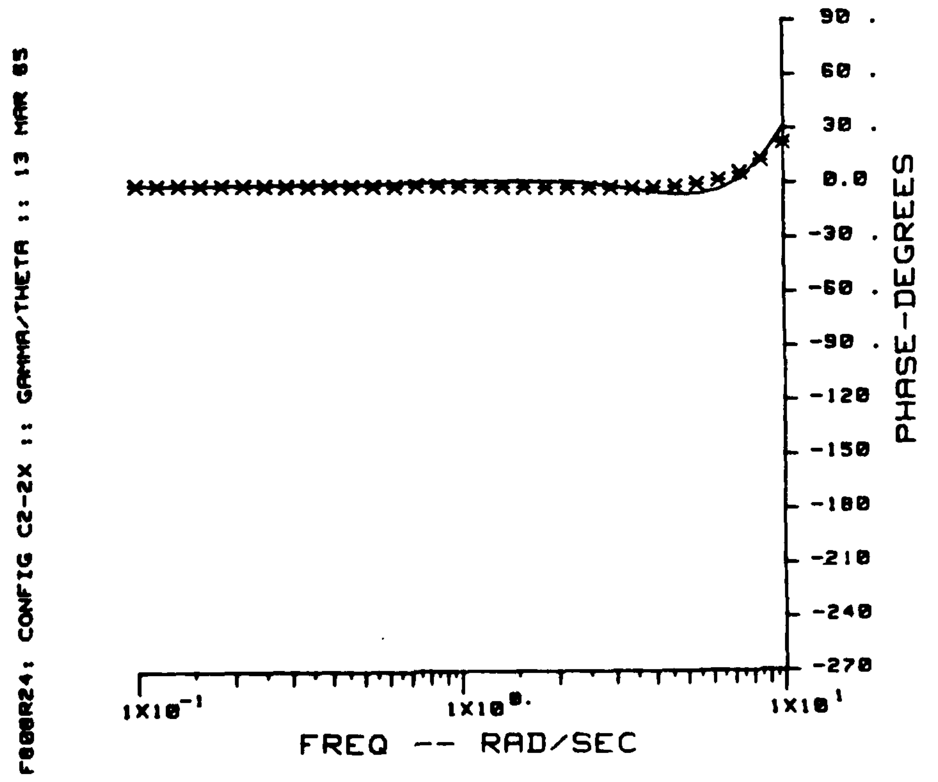


Figure D-49. $(\dot{h}_p/e)$ EQUIVALENT SYSTEM, CONFIGURATION C2-2x, FLIGHT 808, RECORD 24

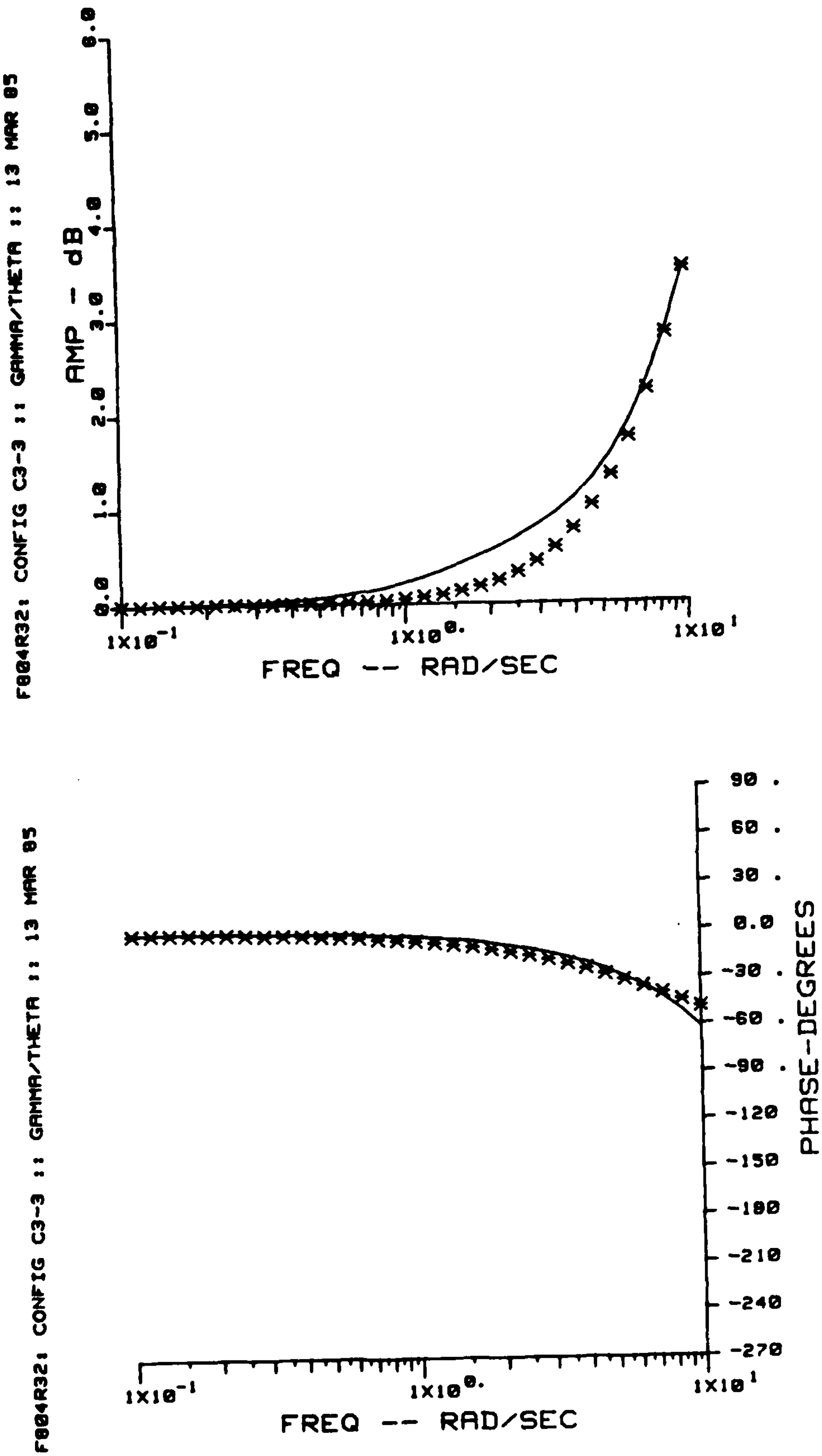


Figure D-50. ($\dot{h}_p/\theta$) EQUIVALENT SYSTEM, CONFIGURATION C3-3, FLIGHT 804, RECORD 32

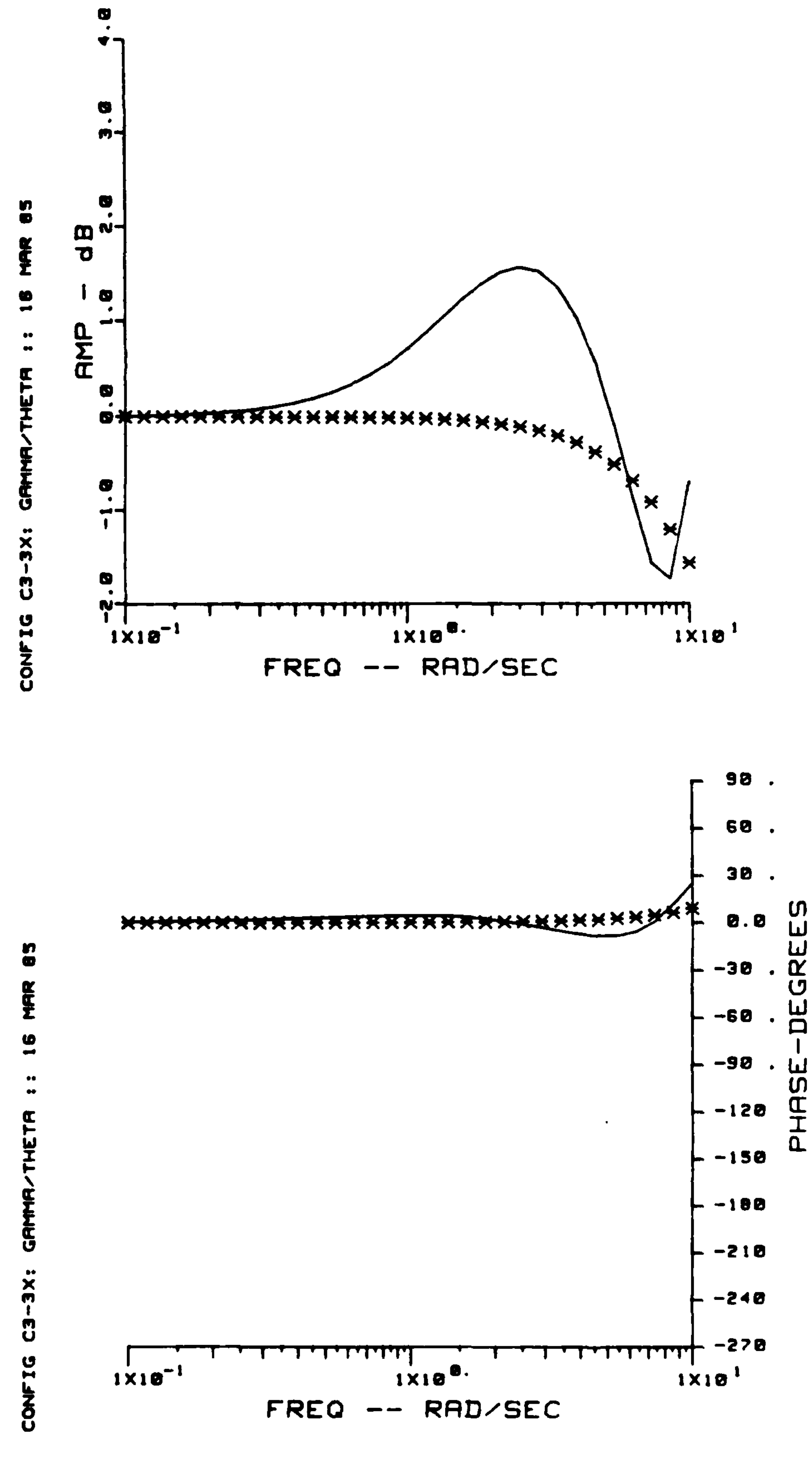


Figure D-51. ($\dot{h}_p/e$) EQUIVALENT SYSTEM, CONFIGURATION C3-3x, FLIGHT 808, RECORD 37

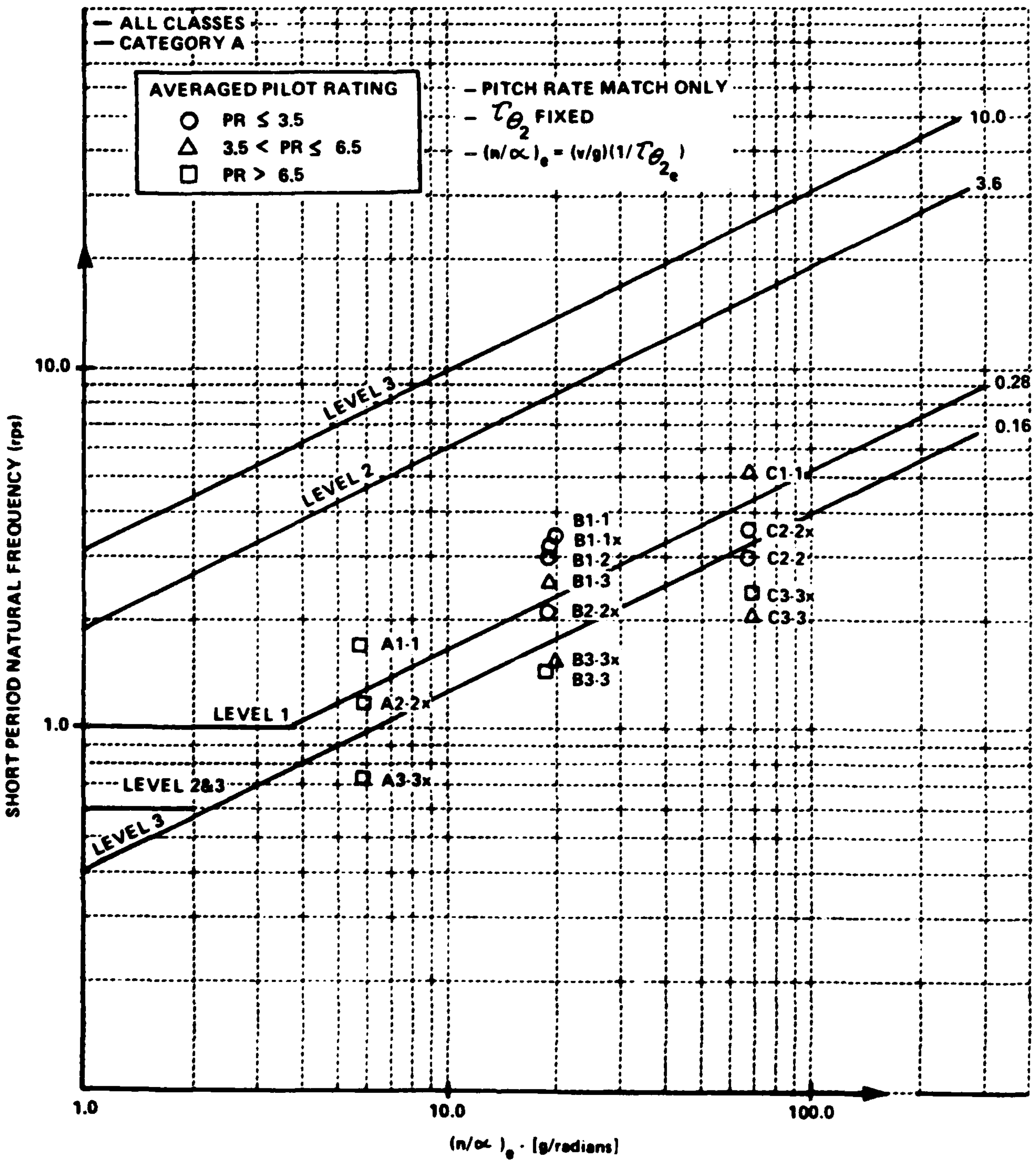


Figure D-52. SHORT PERIOD FREQUENCY REQUIREMENT, MIL-F-8785C, PITCH RATE ONLY MATCH, τ_{θ_2} FIXED (TABLE D-I)

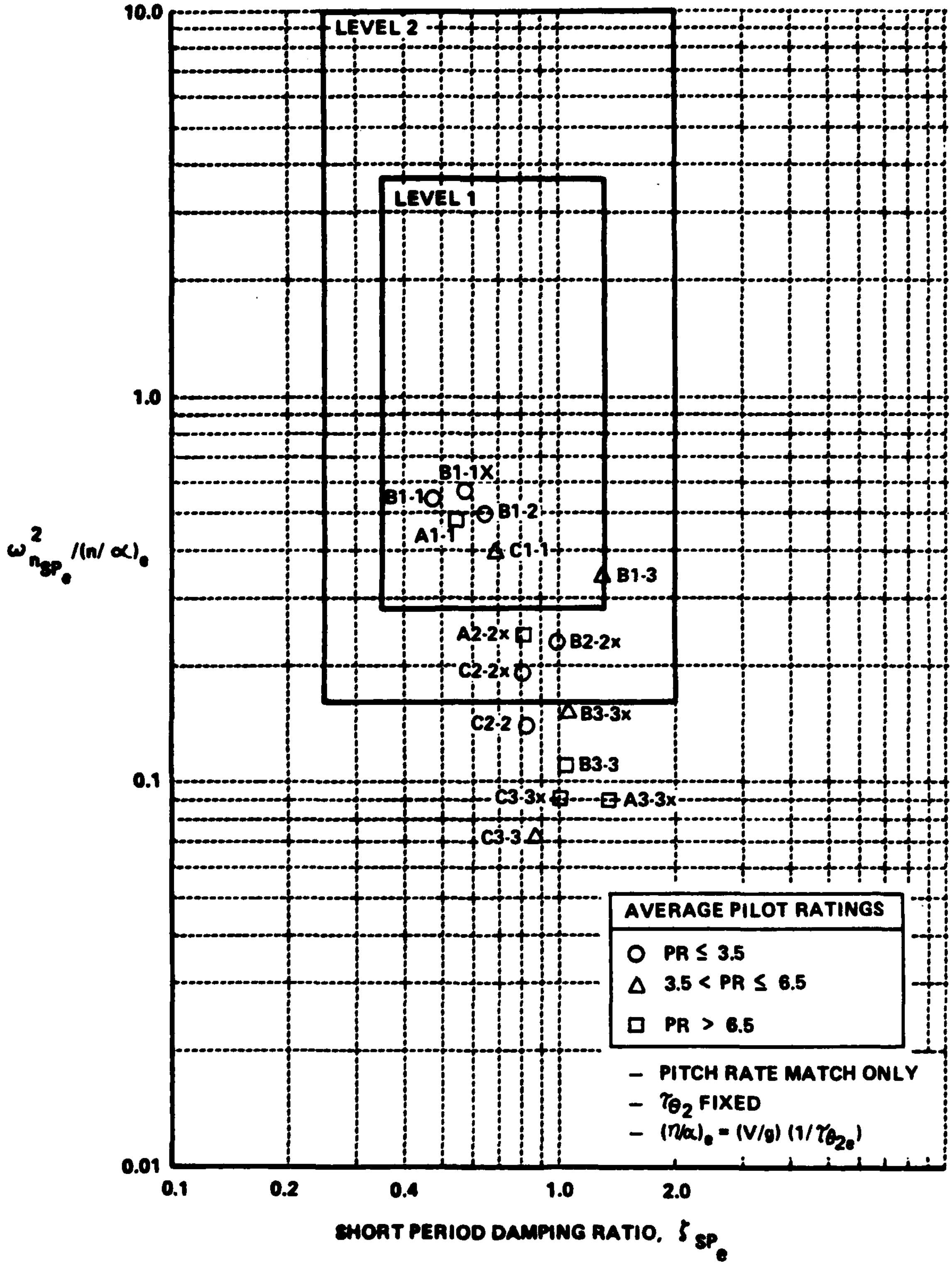


Figure D-53. CAP_e VERSUS ζ_{sp_e} PITCH RATE ONLY MATCH, τ_{θ_2} FIXED (TABLE D-I)

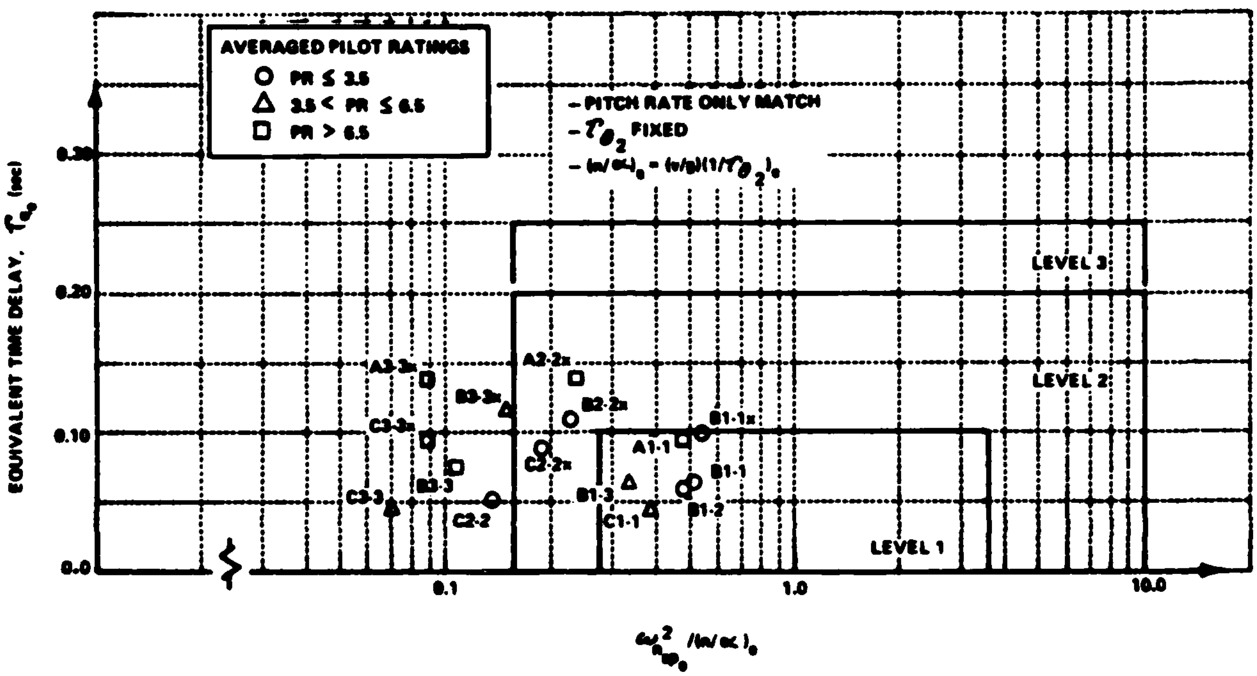


Figure D-54. EQUIVALENT TIME DELAY VERSUS CAP_e, PITCH RATE ONLY MATCH, τ_{θ_2} FIXED (TABLE D-I)

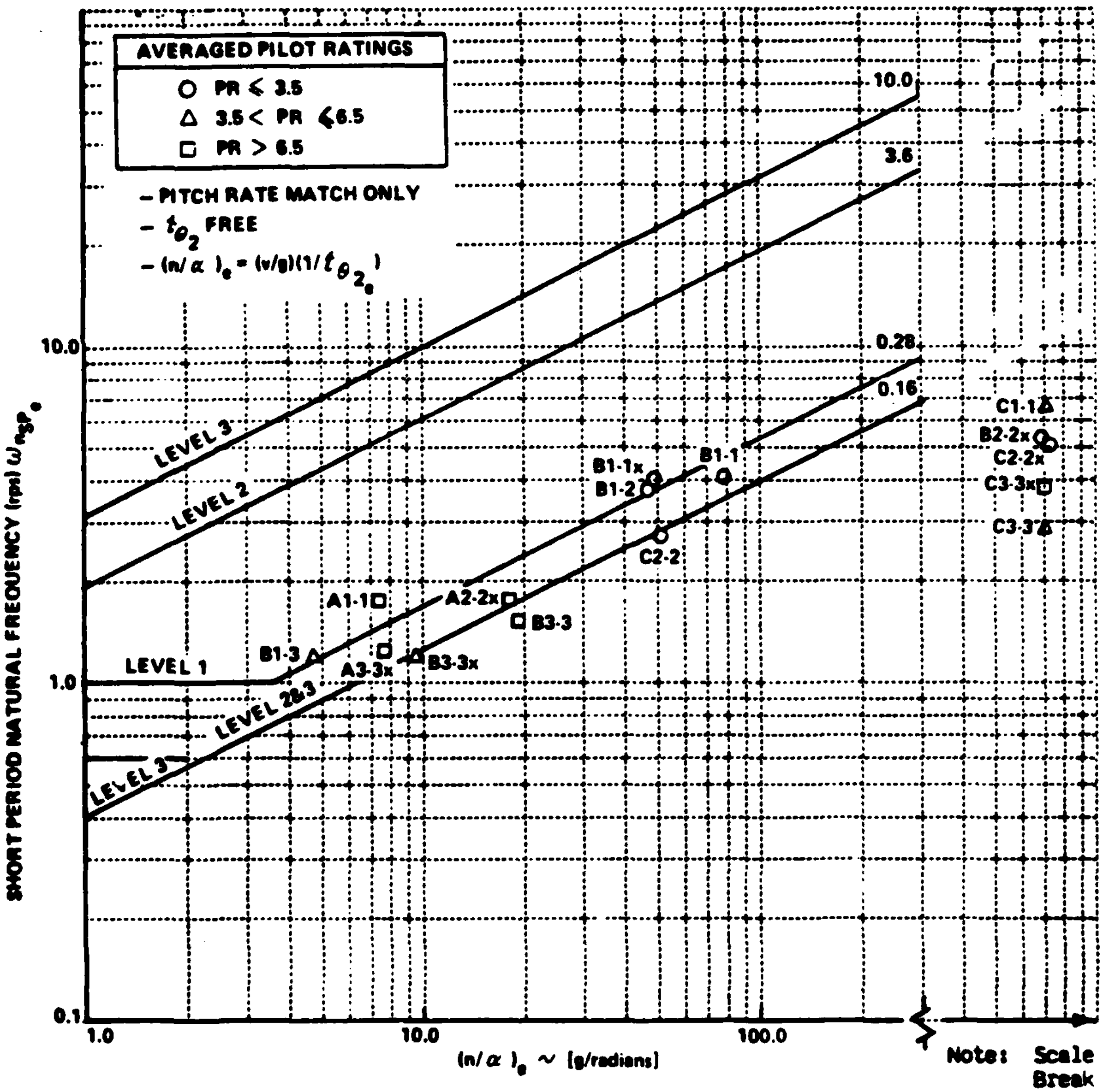


Figure D-55. SHORT PERIOD FREQUENCY REQUIREMENT, MIL-F-8785C, PITCH RATE MATCH ONLY, τ_{θ_2} FREE (TABLE D-II)

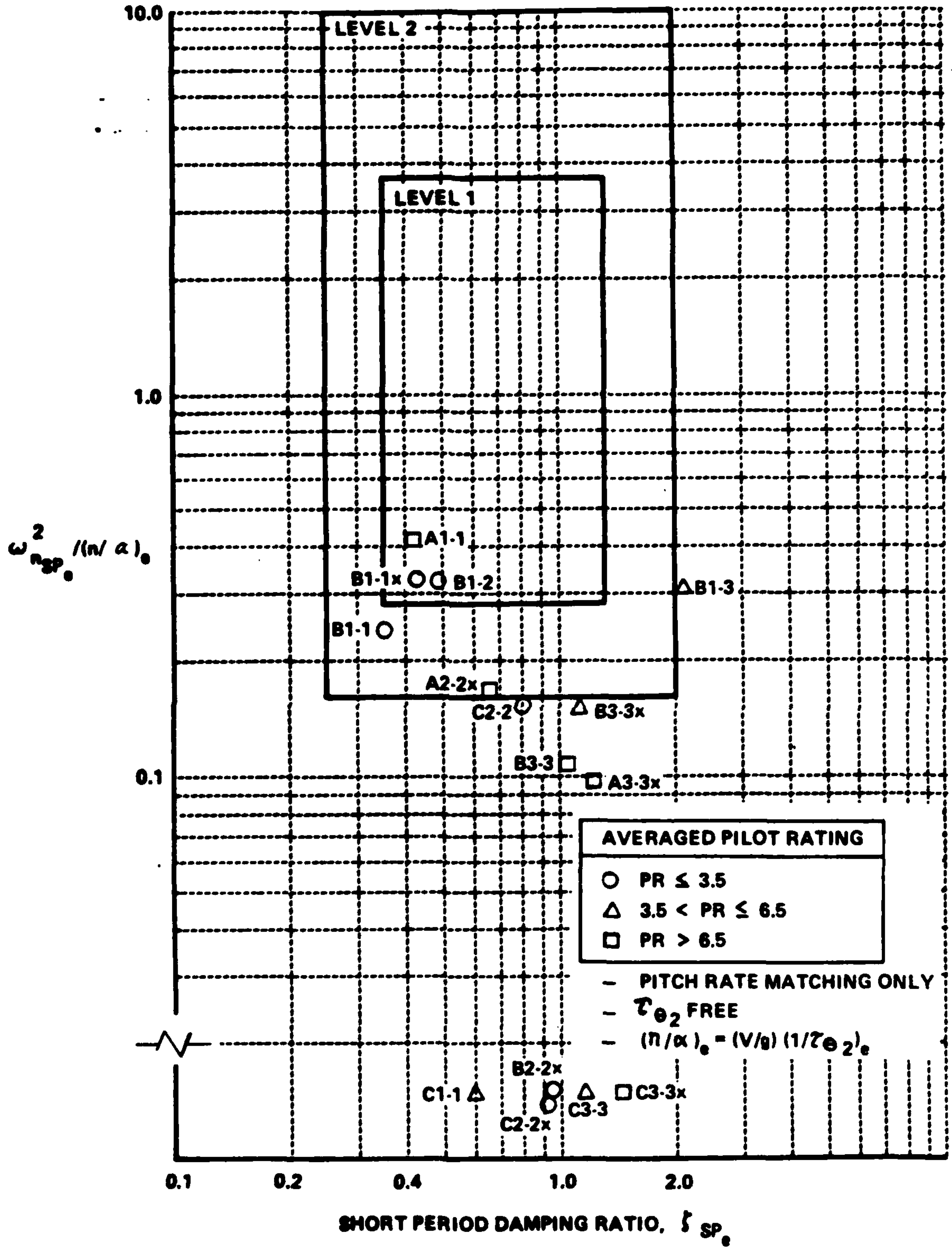


Figure D-56. CAP_e VERSUS ζ_{sp_e} PITCH RATE ONLY MATCH, τ_{θ_2} FIXED (TABLE DII)

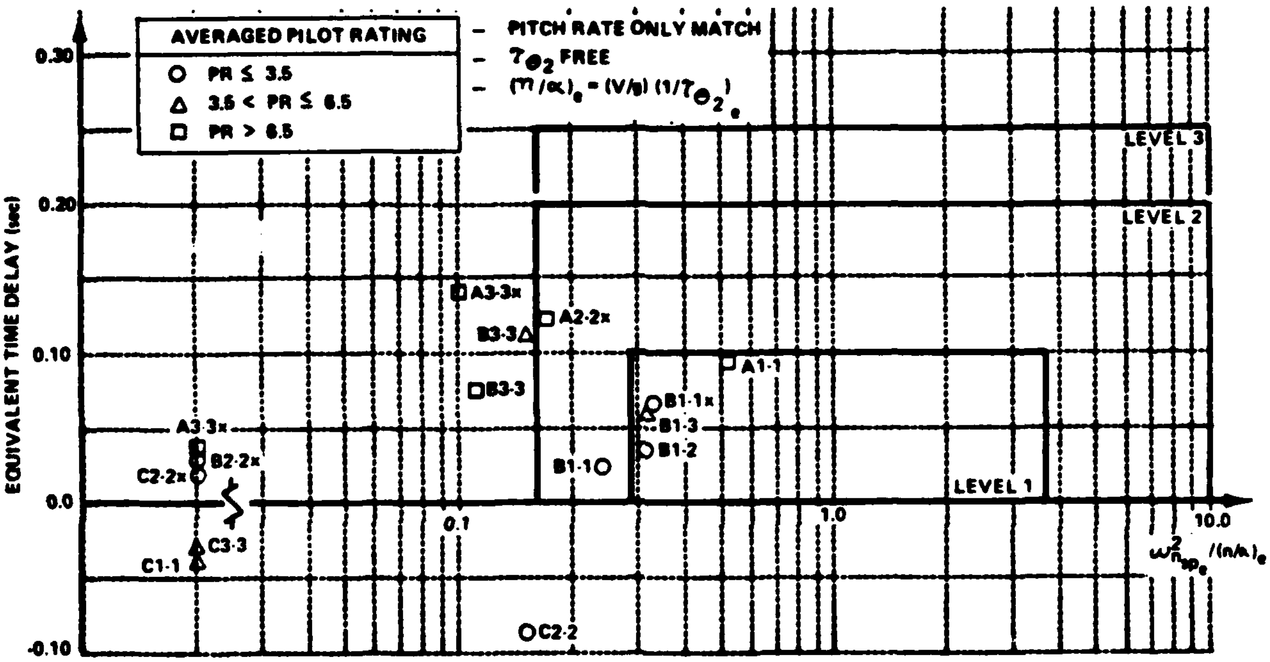


Figure D-57. EQUIVALENT TIME DELAY VERSUS CAP_e, PITCH RATE ONLY MATCH, τ_{θ_2} FREE (TABLE D-II)

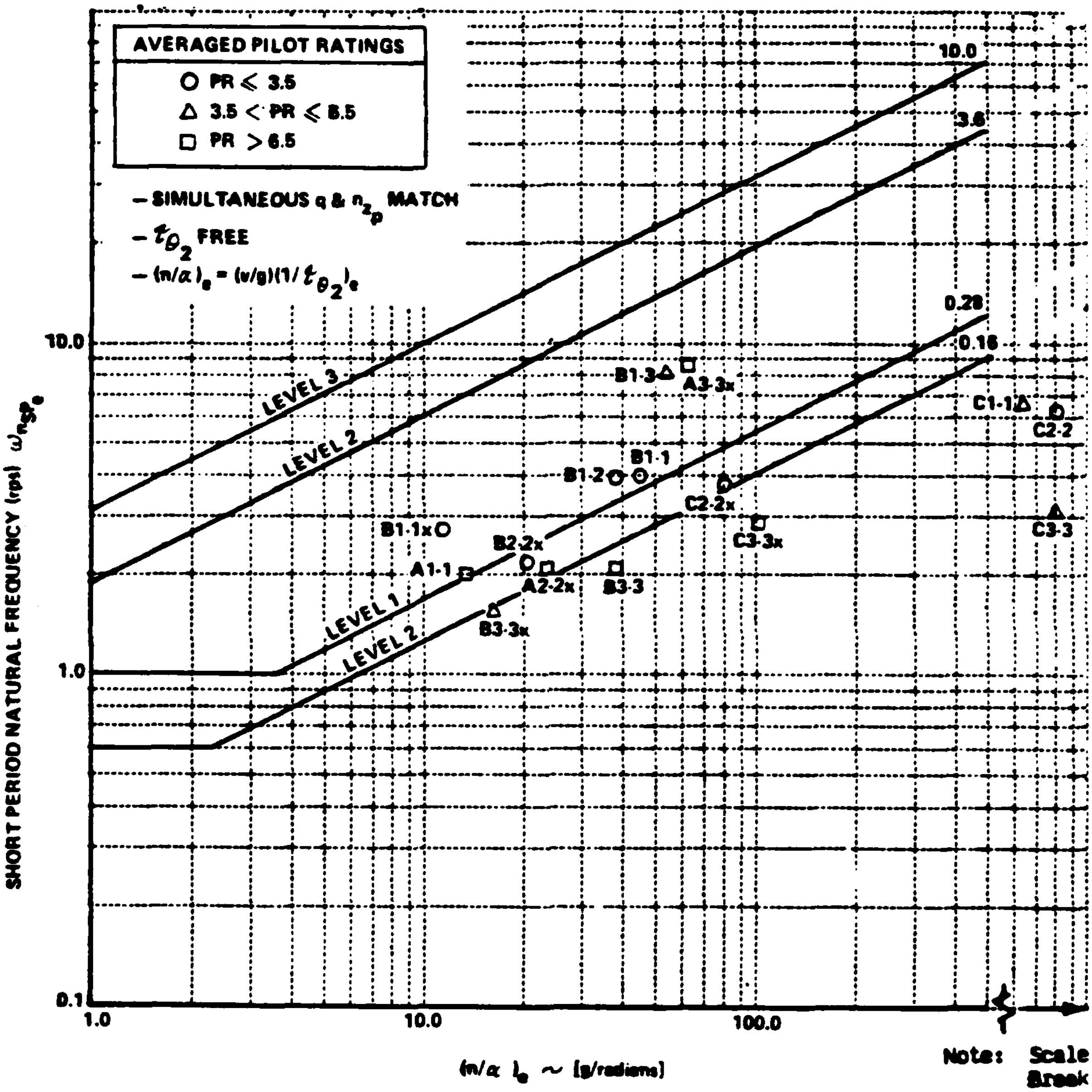


Figure D-58. SHORT PERIOD FREQUENCY REQUIREMENT, PROPOSED MIL-STANDARD, SIMULTANEOUS q and n_{z_p} MATCH (TABLE D-IV)

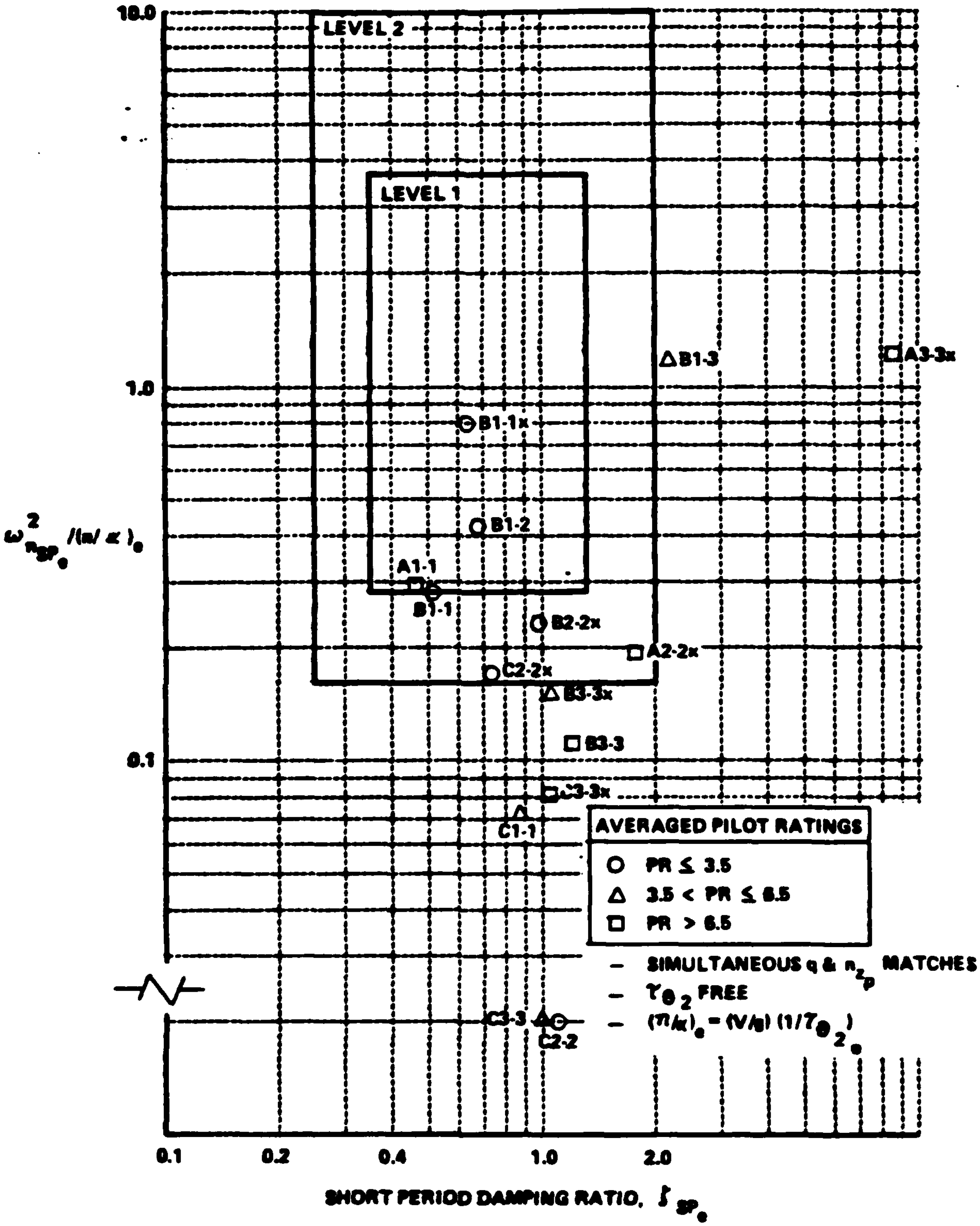


Figure D-59. CAP_e VERSUS ζ_{sp_e}, SIMULTANEOUS q and n_{z_p} MATCH (TABLE D-V)

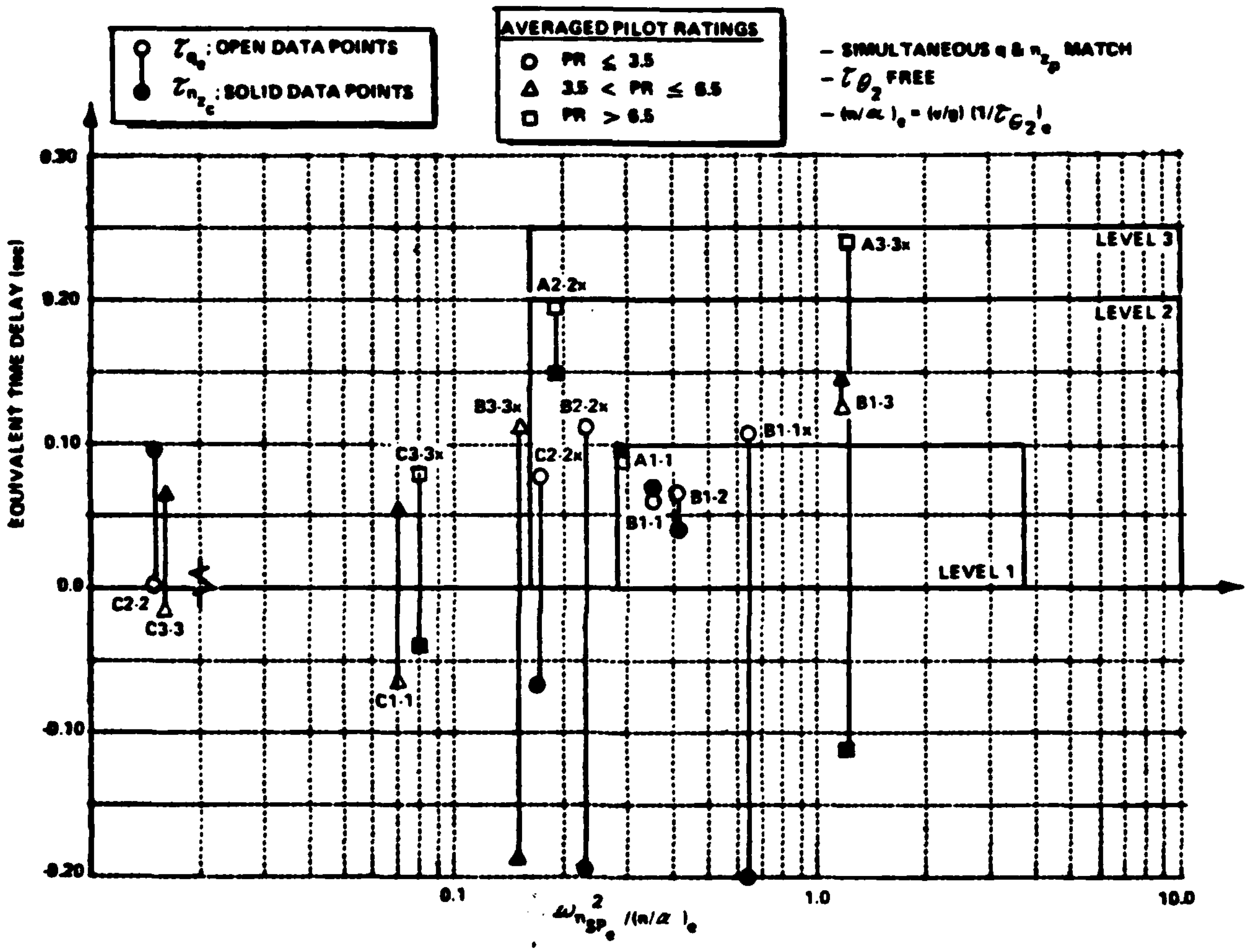


Figure D-60. EQUIVALENT TIME DELAY VERSUS CAP_e, SIMULTANEOUS q and n_{z_p} MATCH (TABLE D-V)

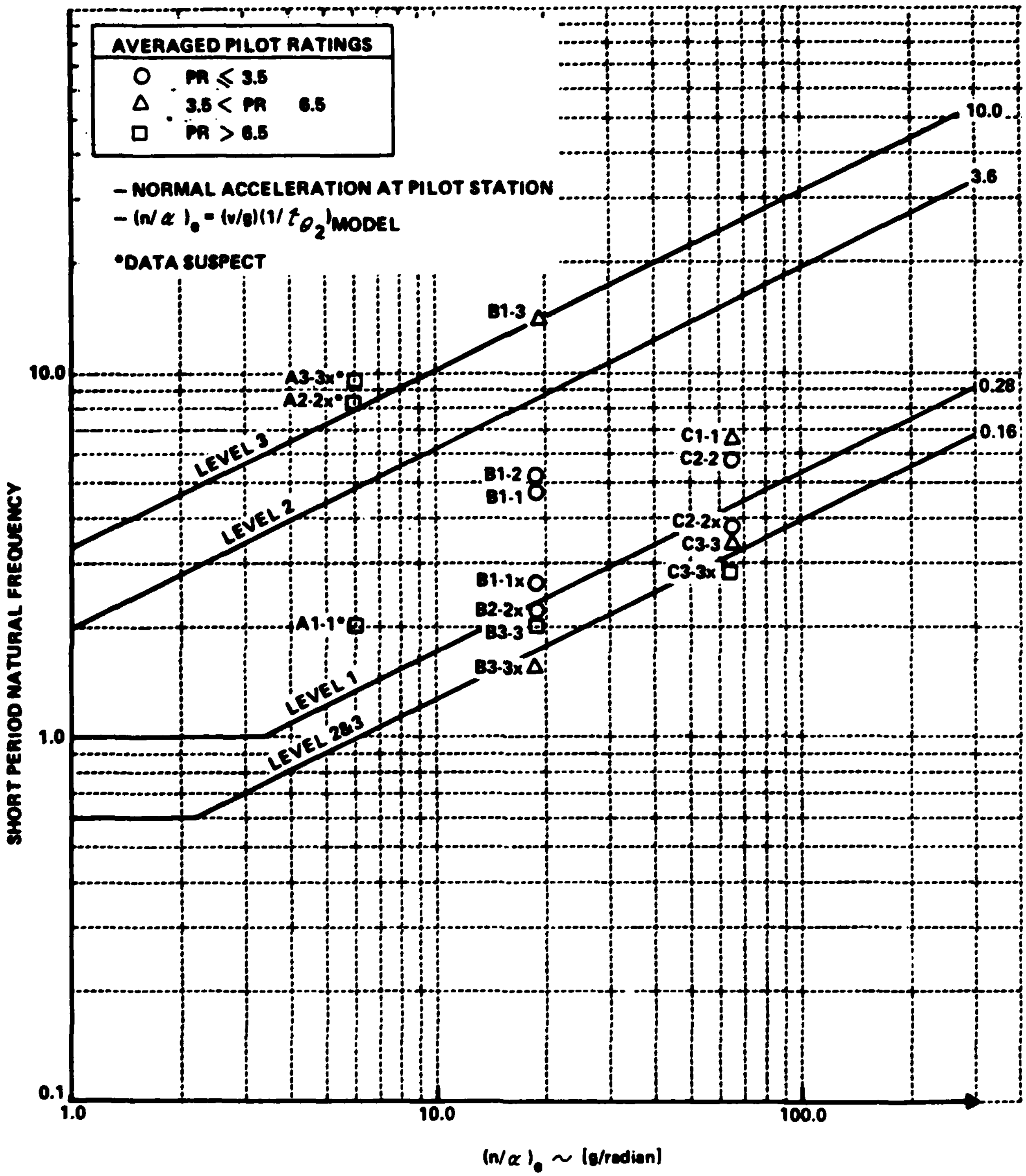


Figure D-61. SHORT PERIOD FREQUENCY REQUIREMENT, NORMAL ACCELERATION MATCHING (0/2) ORDER (TABLE D-III)

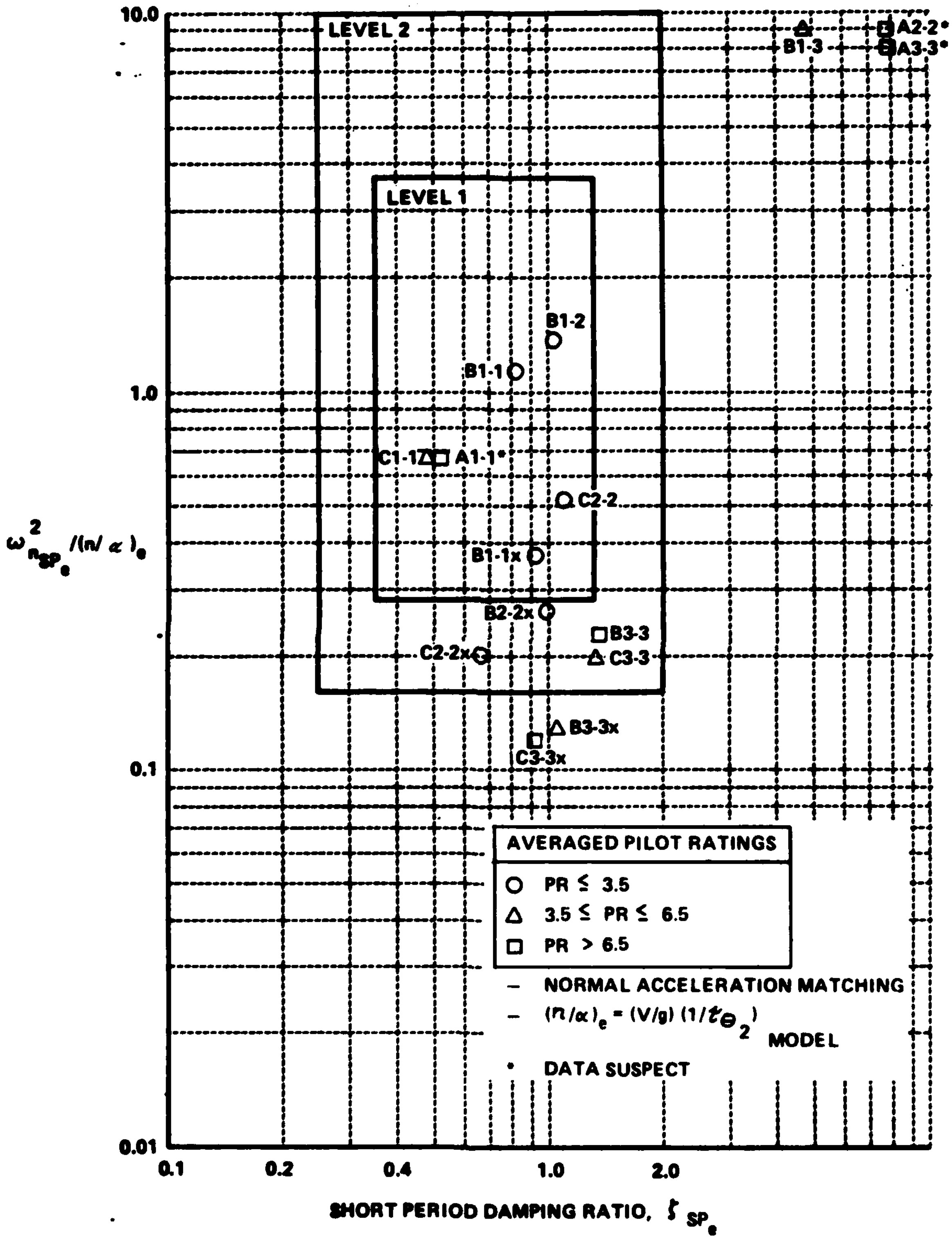


Figure D-62. CAP$_e$ VERSUS SHORT PERIOD DAMPING, NORMAL ACCELERATION MATCHING (0/2) ORDER (TABLE D-III)

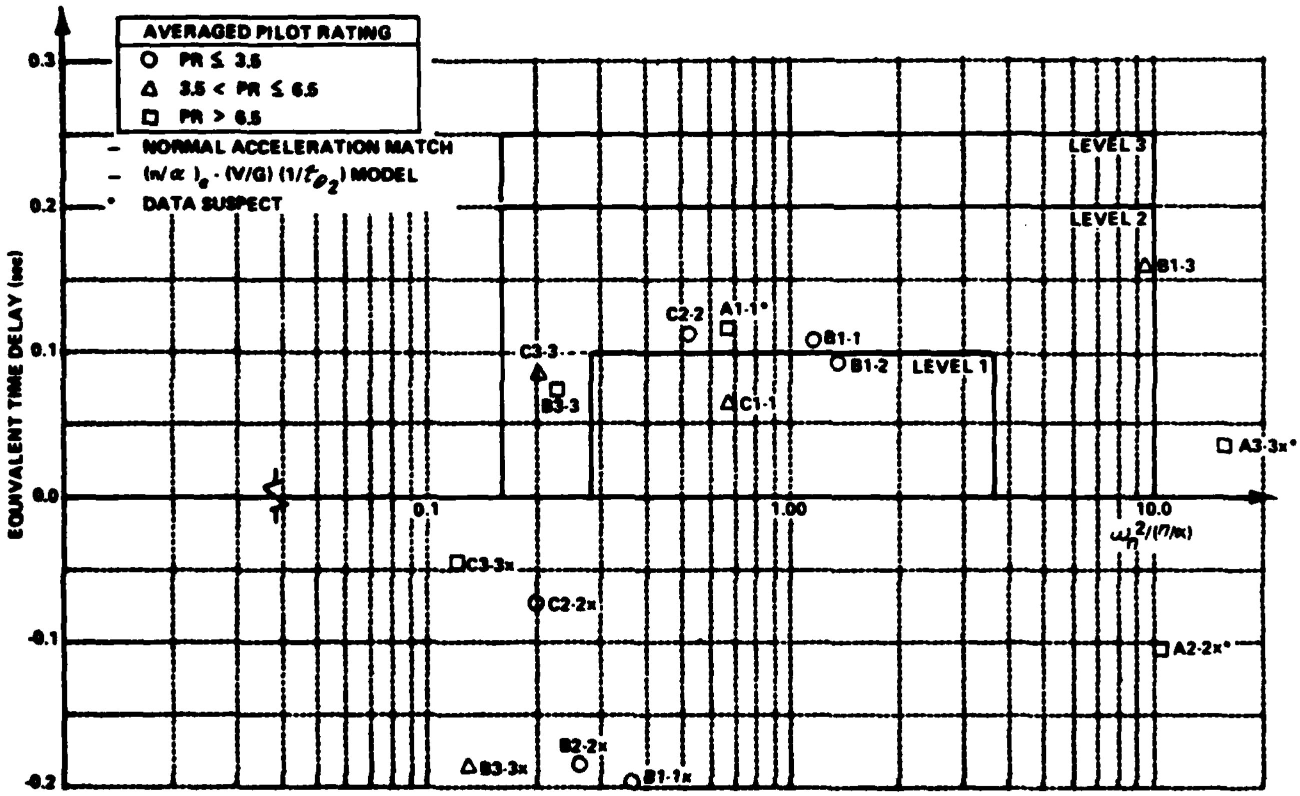


Figure D-63. EQUIVALENT TIME DELAY VERSUS CAP_e, NORMAL ACCELERATION MATCHING (0/2) ORDER (TABLE D-III)

Appendix E
OPEN-LOOP FREQUENCY RESPONSE

In this appendix, the open-loop pitch rate to pitch stick force (q/F_{es}) frequency responses are plotted in a Nichol's chart format.

The frequency responses were generated using the equivalent system models of the Fast Fourier Transformation data (Appendix D). Both the τ_{θ_2} free (*) and fixed (o) cases are plotted. The τ_{θ_2} free models were used exclusively as the pitch transfer functions for any analyses since these results most closely fit the flight data. The τ_{θ_2} fixed responses are plotted for comparison.

The frequency response data were used to calculate the ingredients of the bandwidth criterion (Section 6). Equivalent time delay values were used in lieu of the bandwidth criterion's approximate time delay measure calculated from frequency responses. These two measures have been shown to be closely correlated, and the appropriate flying qualities boundaries were used (Reference 5).

In the Nichol's chart format, frequency is an independent variable. The 1.0 rad/sec frequency point is denoted by the symbol <> on each chart. The plots have been normalized such that the 1.0 rad/sec point coincides with 0 dB open-loop gain for the τ_{θ_2} free cases. The same normalization gain is applied to the τ_{θ_2} fixed response so a direct comparison of the two responses is made in the Nichol's chart format. The frequency points thereafter are:

1.2	2.2	3.2	4.2	6.0
1.4	2.4	3.4	4.4	7.0
1.5	2.5	3.5	4.5	8.0
1.6	2.6	3.6	4.6	9.0
1.8	2.8	3.8	4.8	10.0 rad/sec
2.0	3.0	4.0	5.0	

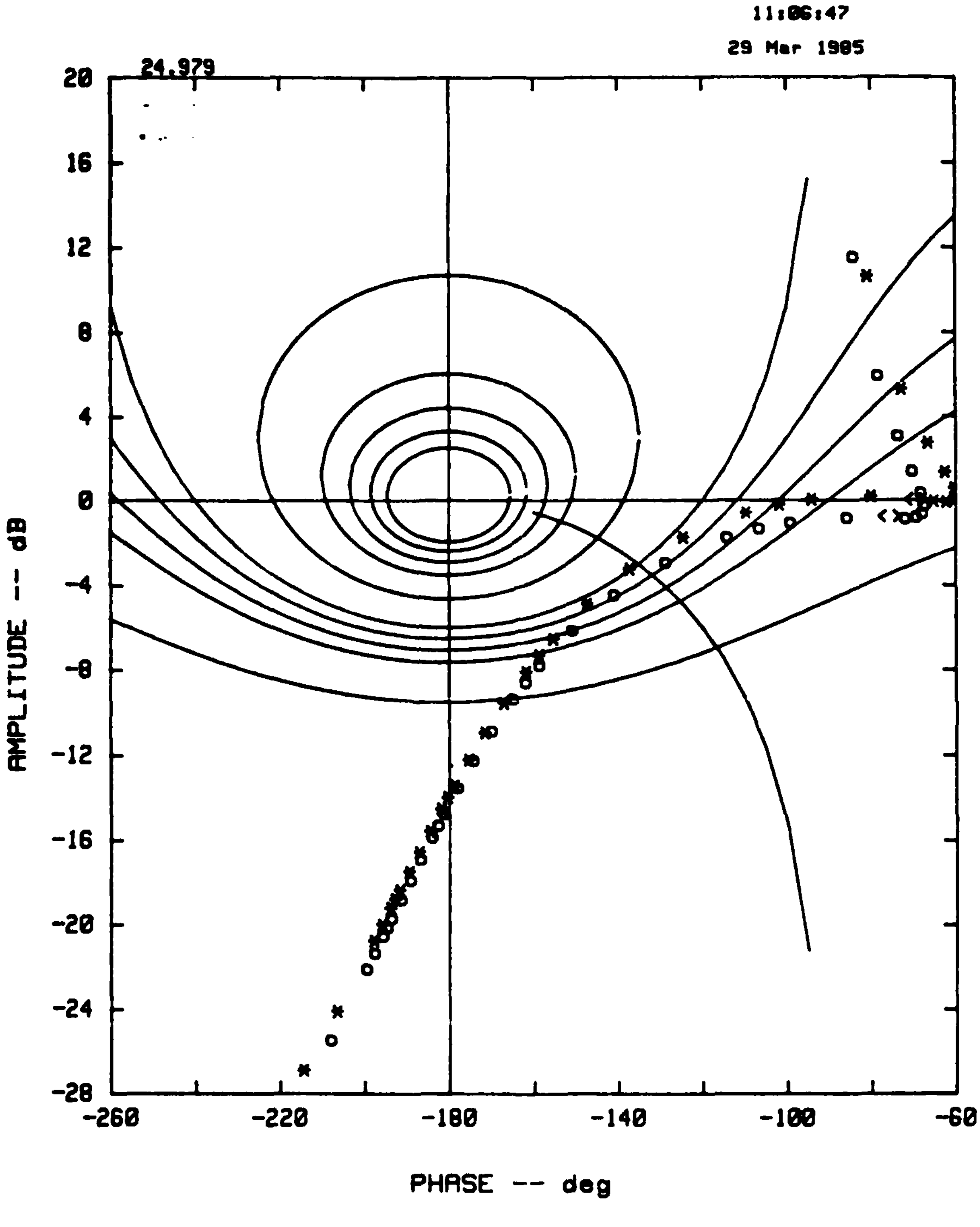


Figure E-1. (α/F_{es}) FREQUENCY RESPONSE FOR CONFIGURATION A1-1, FLIGHT 802, RECORD NO. 09

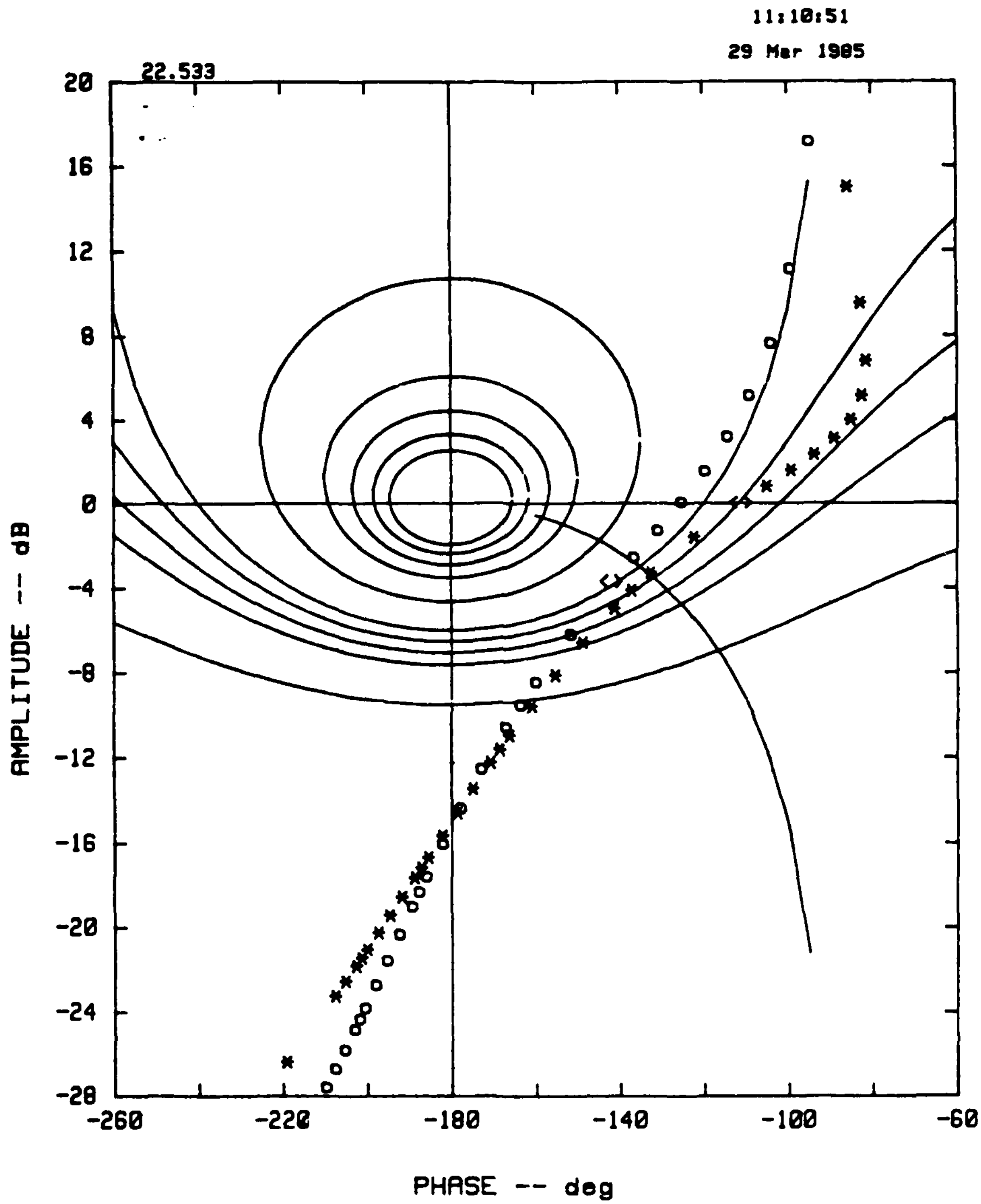


Figure E-2. (q/F_{es}) FREQUENCY RESPONSE FOR CONFIGURATION A2-2x, FLIGHT 802, RECORD NO. 19

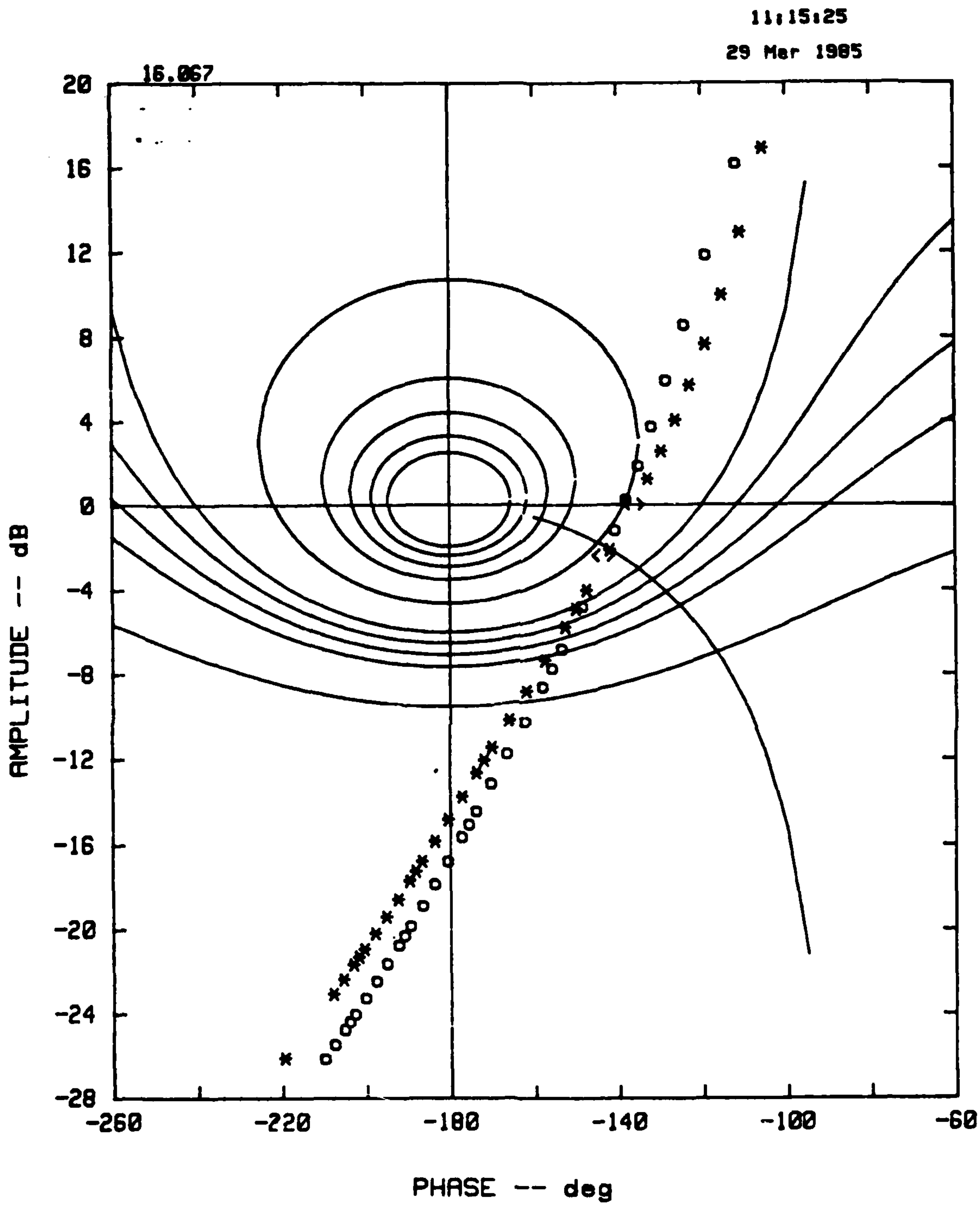


Figure E-3. (q/F_{es}) FREQUENCY RESPONSE FOR CONFIGURATION A3-3x, FLIGHT 803, RECORD NO. 19

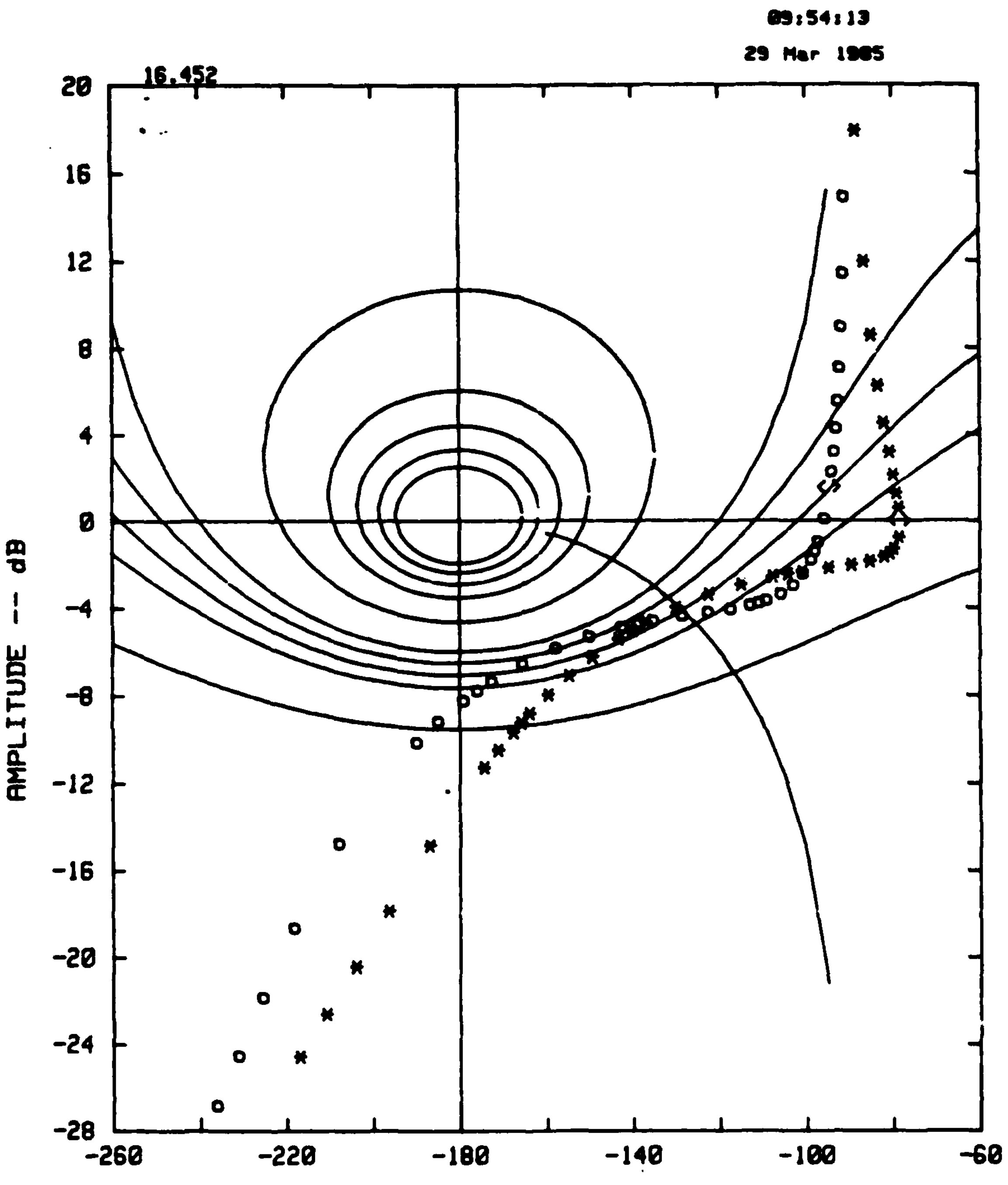


Figure E-4. (q/F_{es}) FREQUENCY RESPONSE FOR CONFIGURATION B1-1, FLIGHT 805, RECORD NO. 14

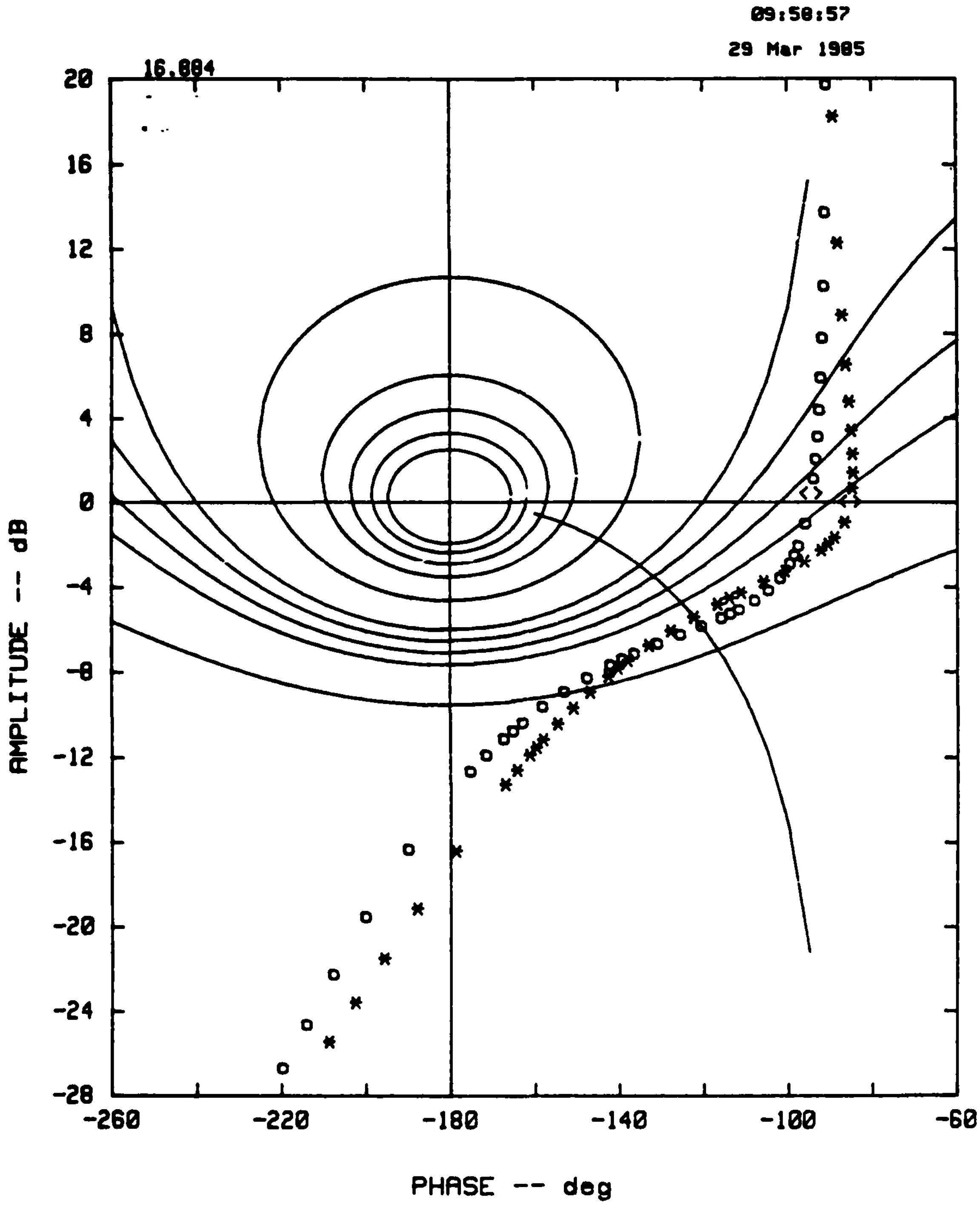


Figure E-5. (q/F_{es}) FREQUENCY RESPONSE FOR CONFIGURATION B1-2, FLIGHT 808, RECORD NO. 07

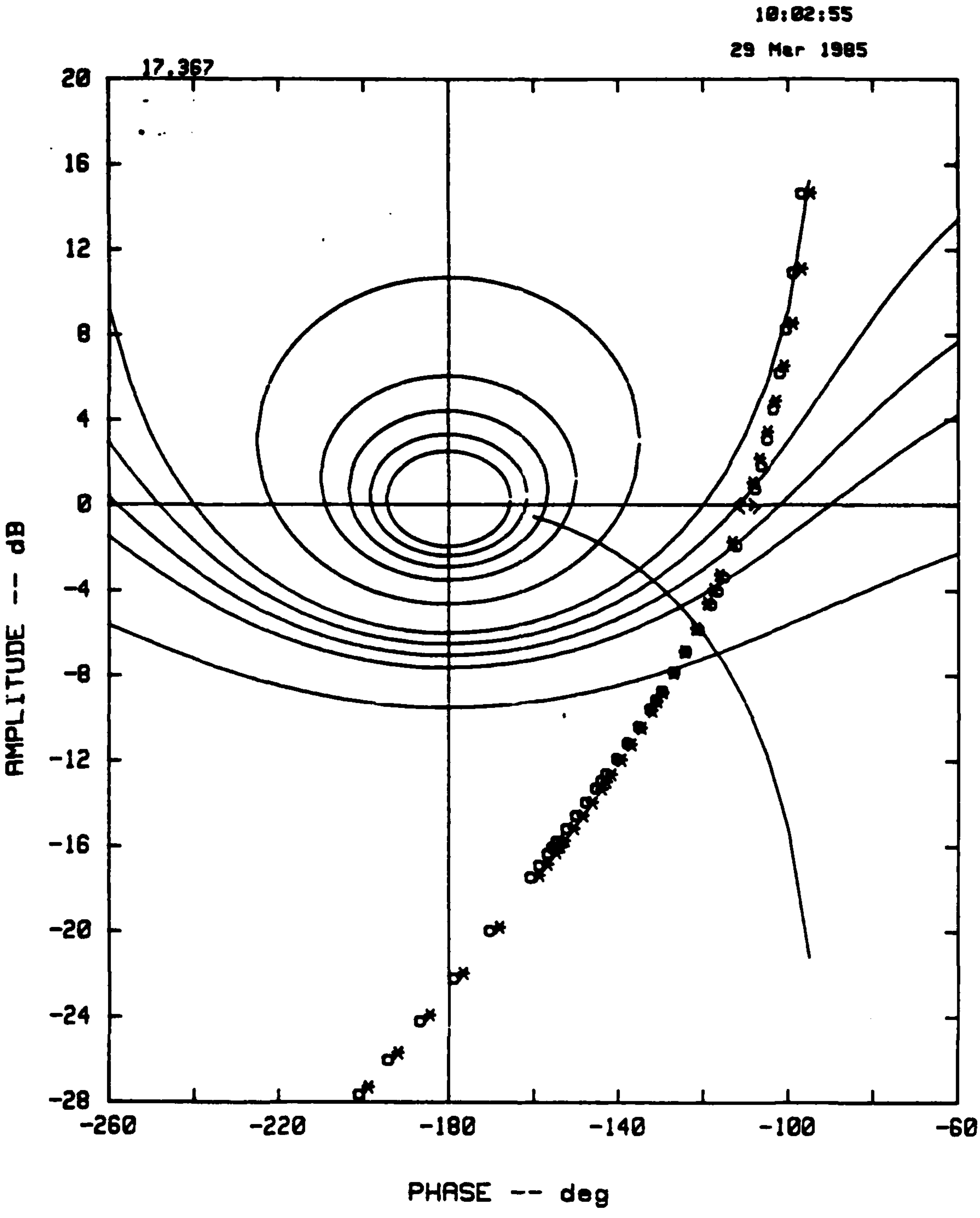


Figure E-6. (q/F_{es}) FREQUENCY RESPONSE FOR CONFIGURATION B1-3, FLIGHT 808, RECORD NO. 27

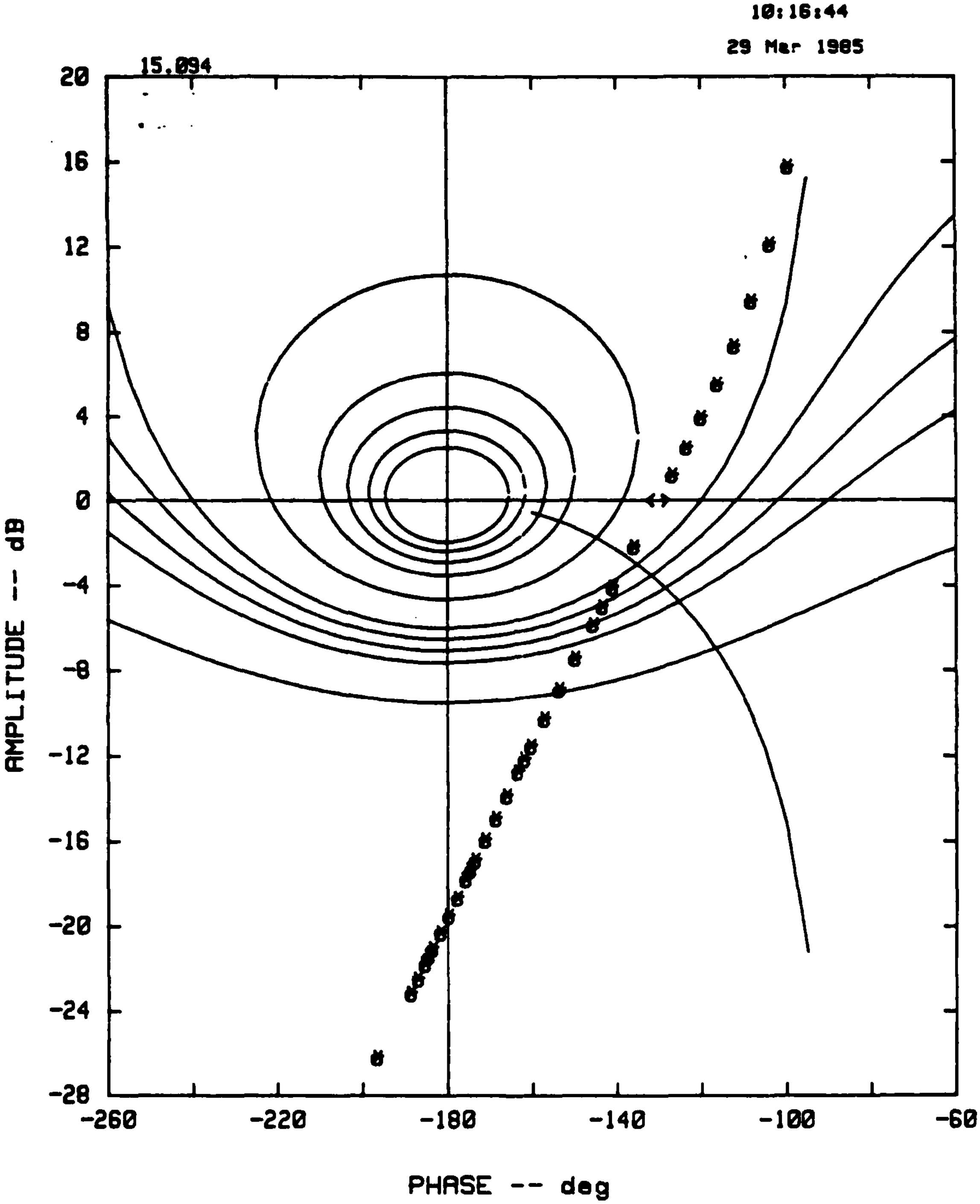


Figure E-7. (q/F_{es}) FREQUENCY RESPONSE FOR CONFIGURATION B3-3, FLIGHT 804, RECORD NO. 09

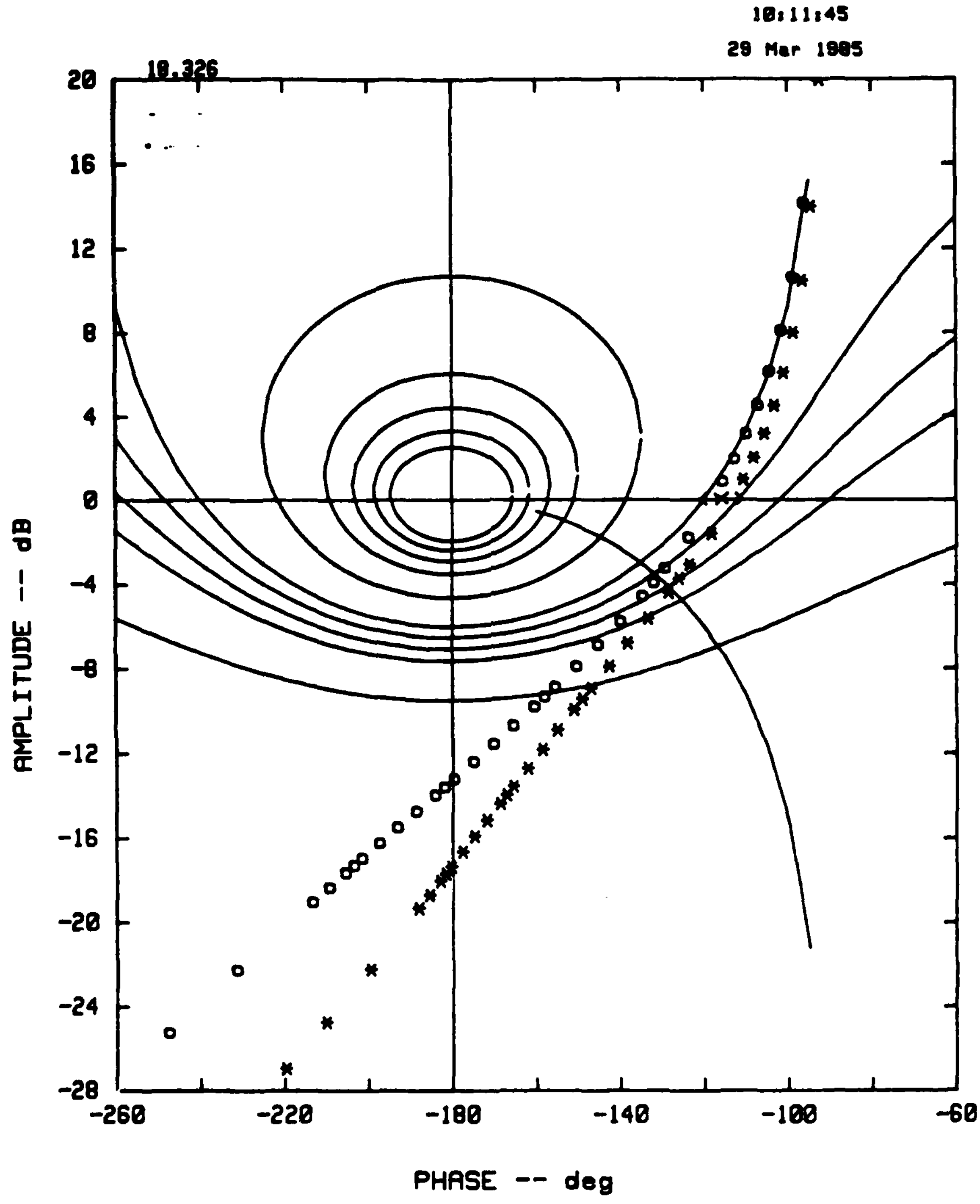


Figure E-8. (q/F_{es}) FREQUENCY RESPONSE FOR CONFIGURATION B2-2x, FLIGHT 808, RECORD NO. 12

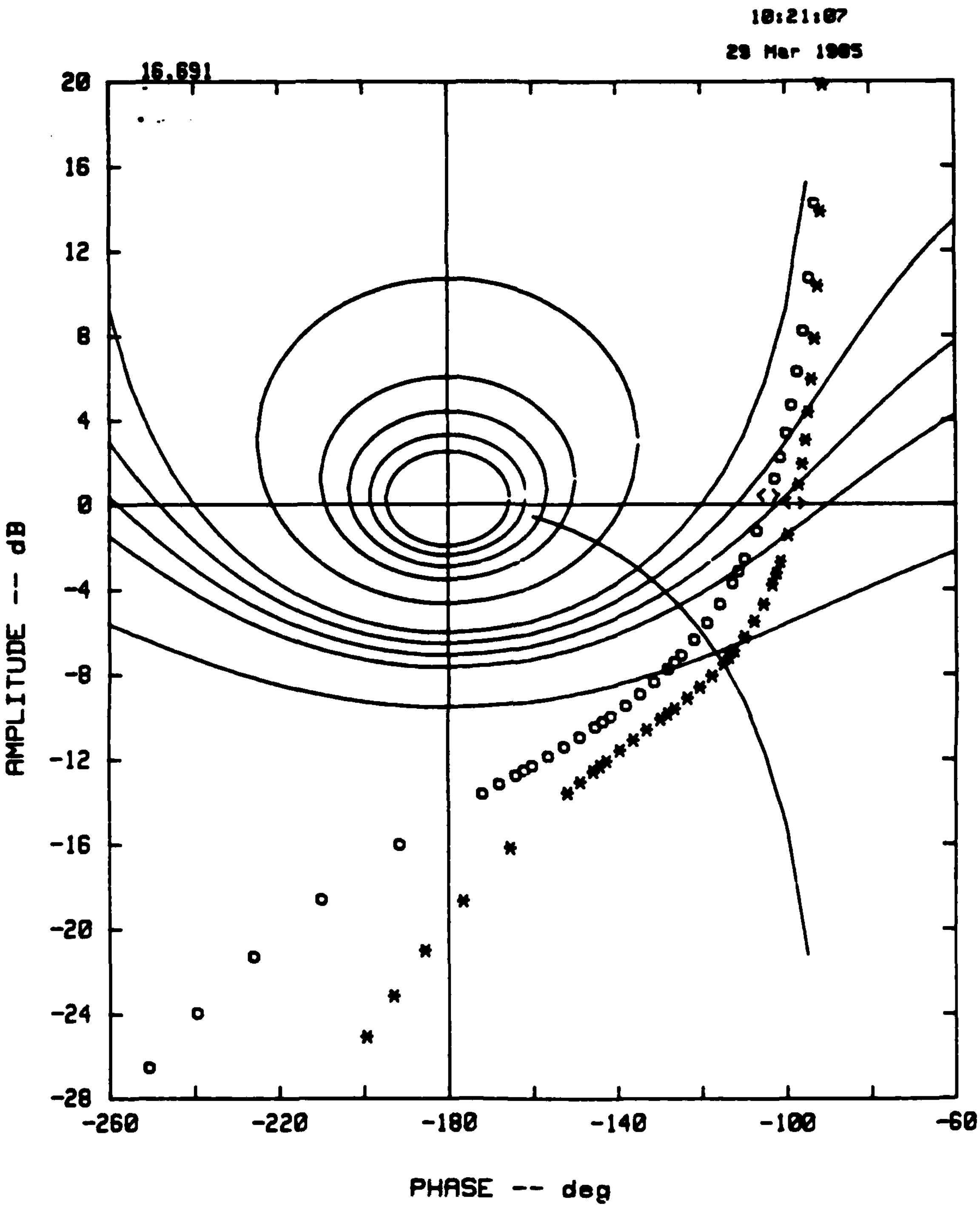


Figure E-9. (q/F_{es}) FREQUENCY RESPONSE FOR CONFIGURATION C1-1, FLIGHT 808, RECORD NO. 18

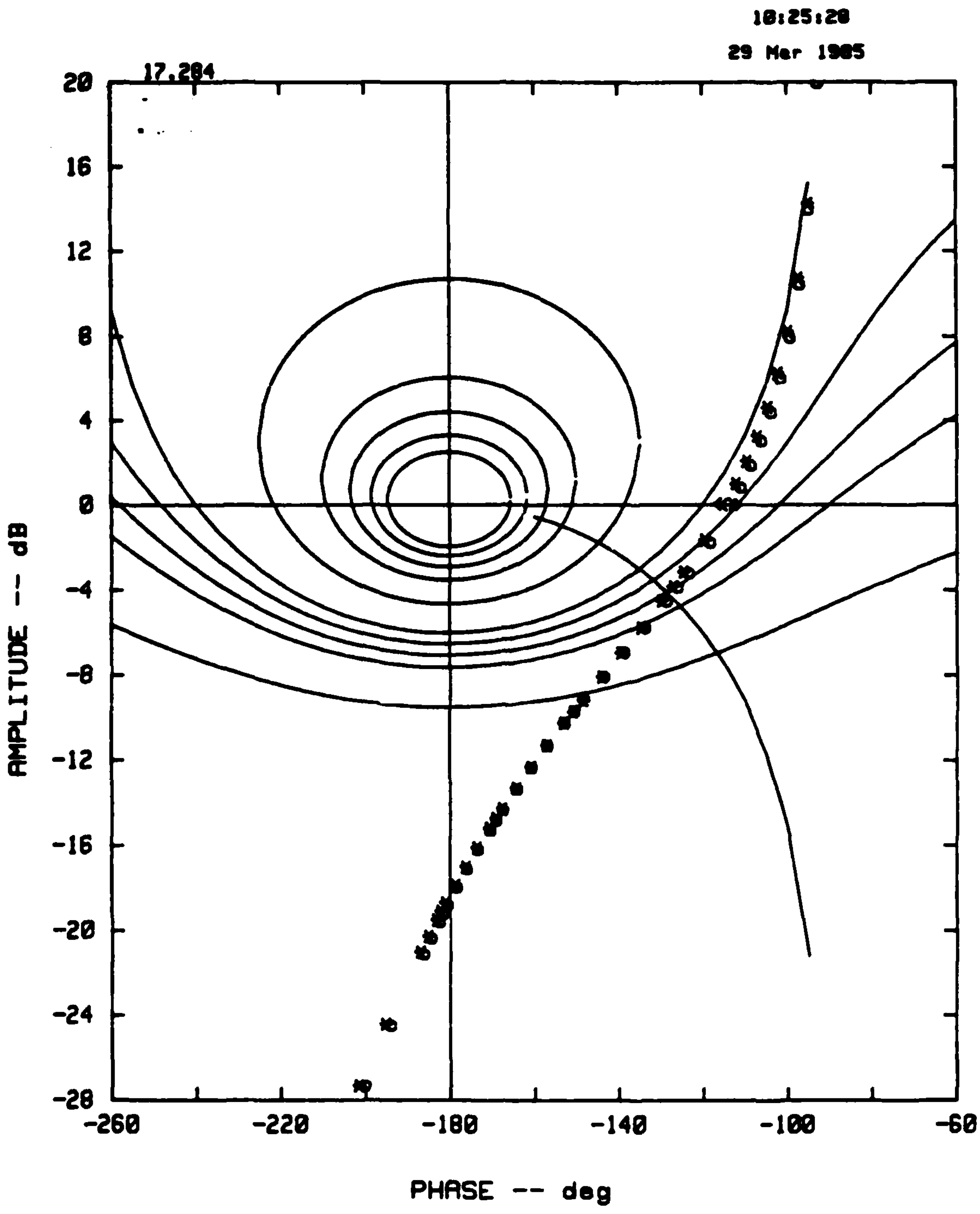


Figure E-10. (q/F_{es}) FREQUENCY RESPONSE FOR CONFIGURATION C2-2, FLIGHT 806, RECORD NO. 23

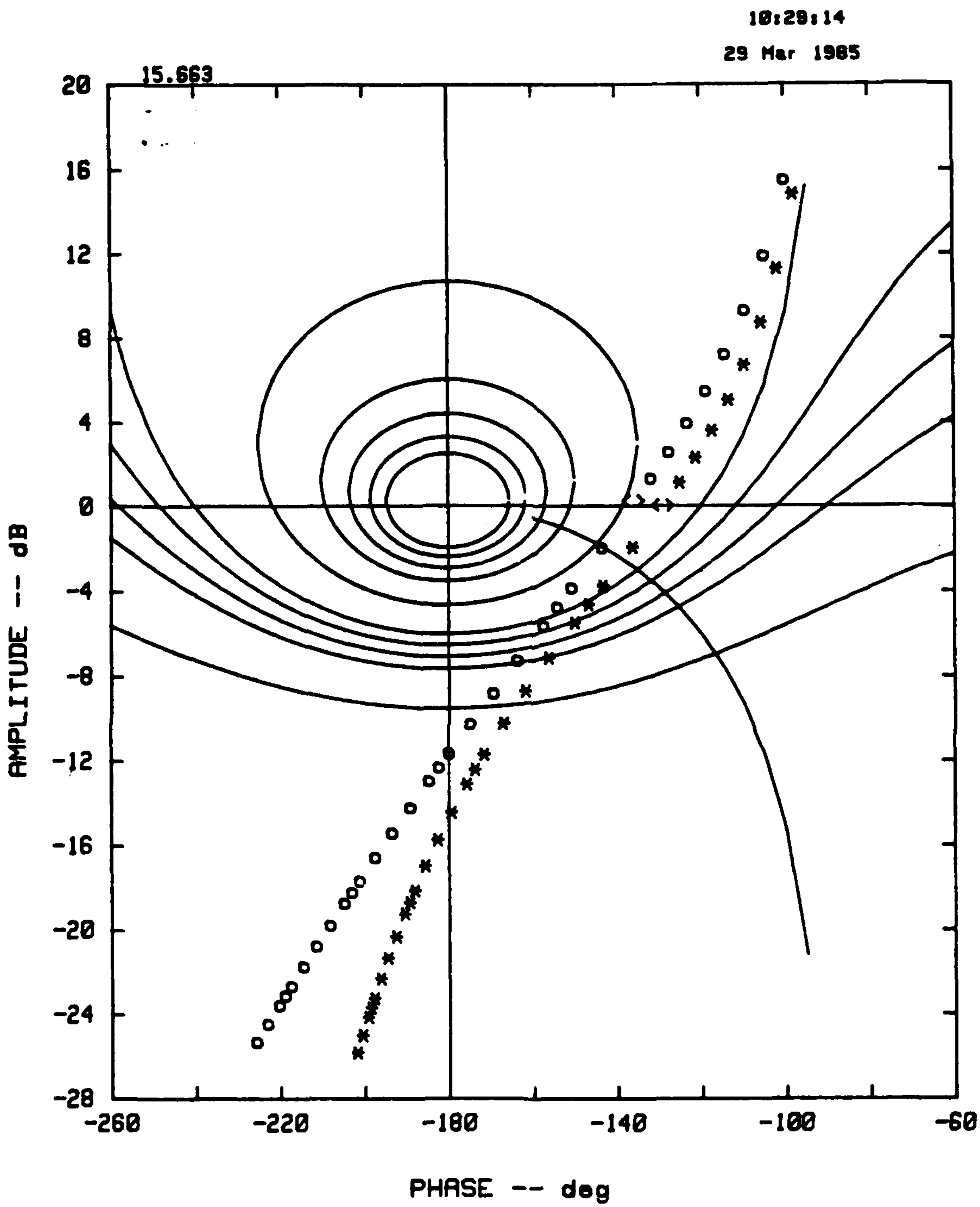


Figure E-11. (q/F_{es}) FREQUENCY RESPONSE FOR CONFIGURATION C3-3, FLIGHT 804, RECORD NO. 32

Appendix F
NEAL-SMITH CRITERION

The Neal-Smith criterion was applied to the experiment results. In conjunction with this analysis, several correlations were performed:

- In Figures F-1 through F-11, each configuration is mapped into the Neal-Smith parameter plane for variations in assumed task bandwidth and pilot time delay.

- In Figures F-12 through F-19, the experiment configurations are plotted against the Neal-Smith criterion for assumed pilot time delays of .2 and .3 seconds and for bandwidths from 2.0 to 3.5 radians/second. Averaged Pilot Ratings are shown.

- In Figures F-20 through F-30, the compensated frequency responses of each configuration for a pilot time delay of .3 seconds and 3.0 rad/sec bandwidth are presented in a Nichol's chart. These criterion parameters were found to be representative for this experiment (see Section 6). The frequency points plotted are identical to those in Appendix E.

The Neal-Smith analysis was conducted using the lower order, transfer functions obtained from the pitch rate only, τ_{θ_2} free equivalent system models of the FFT data. The data are, consequently, viewed as curve fits of the actual configuration frequency responses. This was done for the sake of convenience to bypass the noise associated with the raw data.

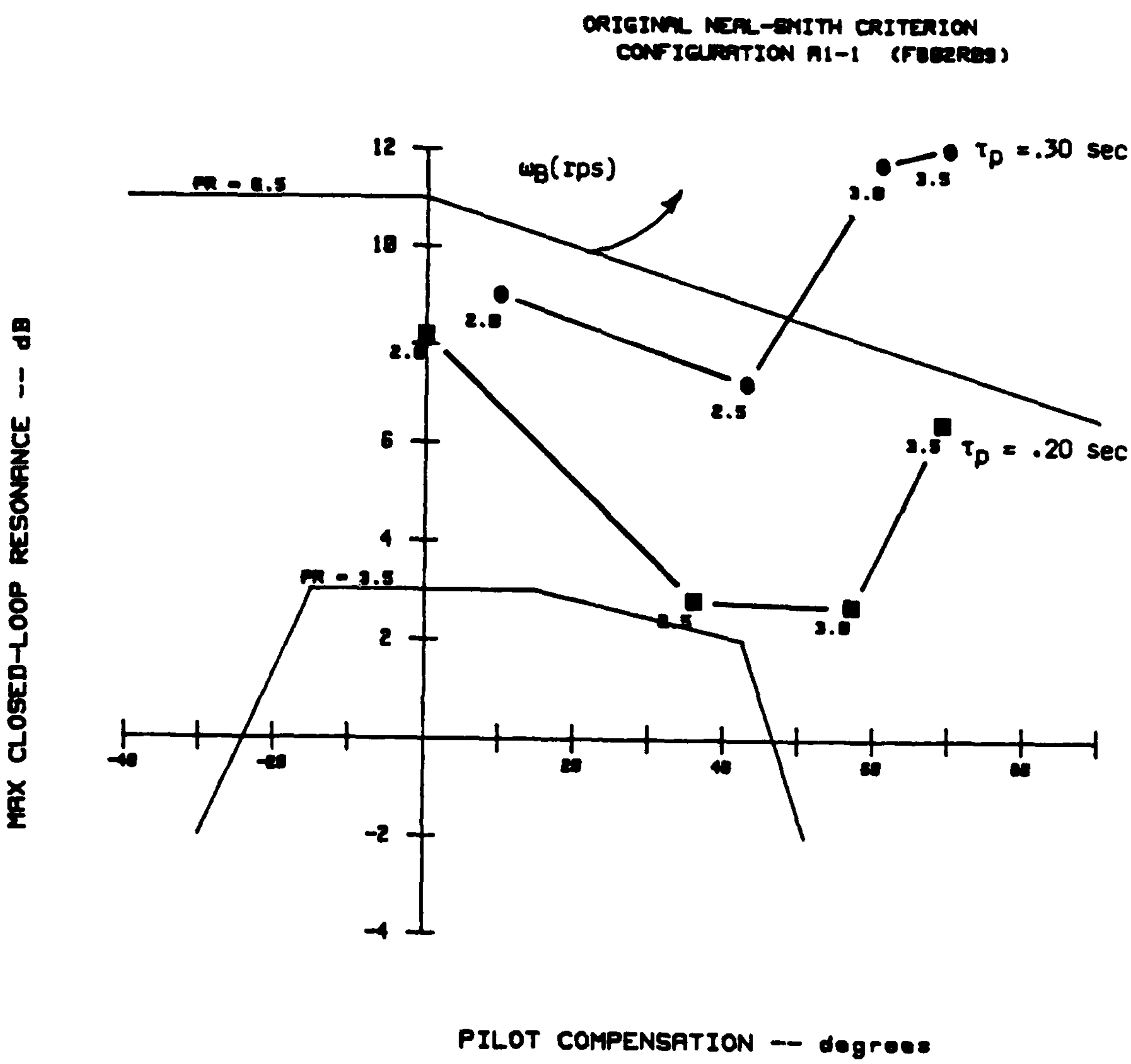


Figure F-1. NEAL SMITH PARAMETER PLANE, CONFIGURATION A1-1

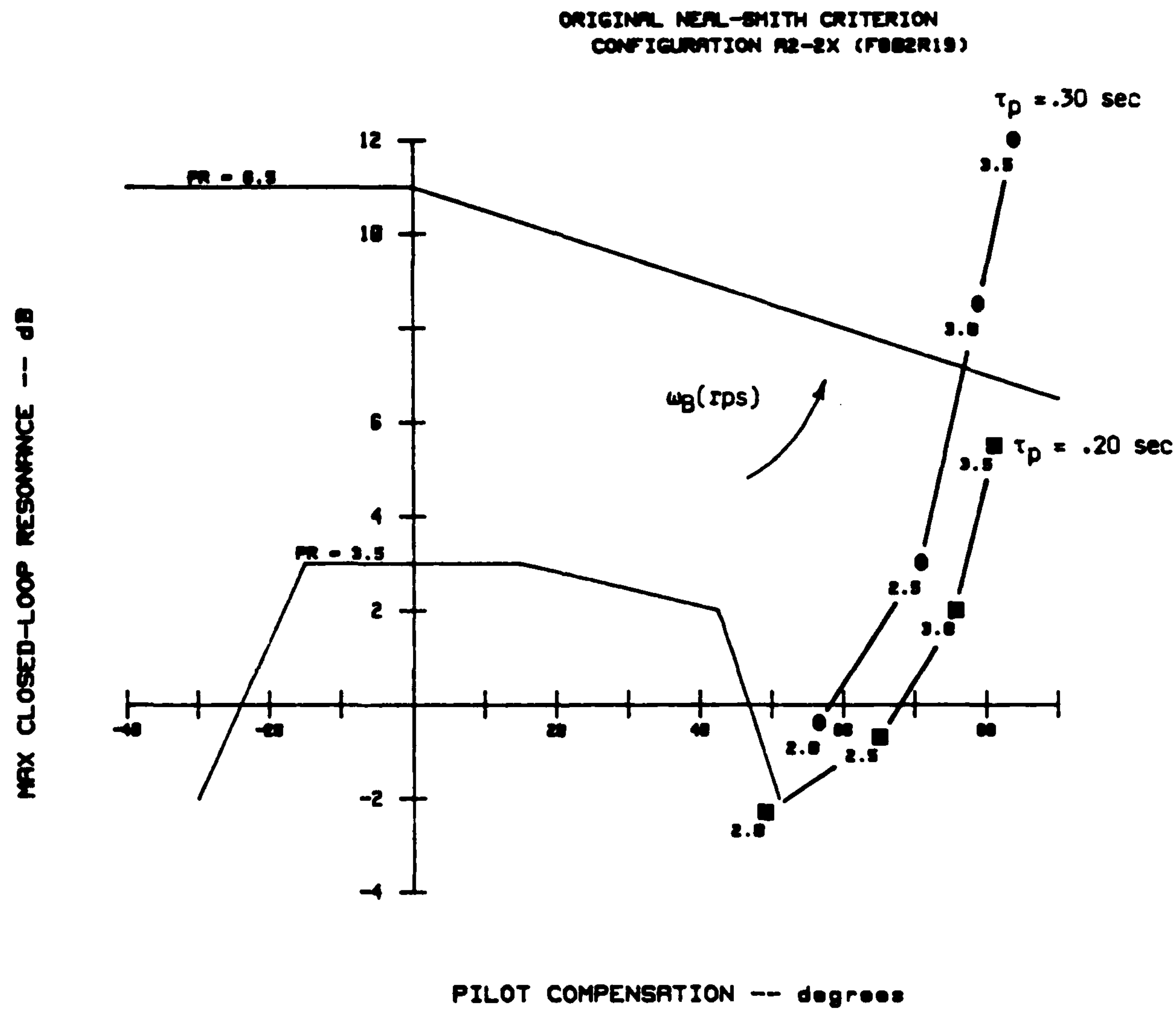


Figure F-2. NEAL SMITH PARAMETER PLANE, CONFIGURATION A2-2x

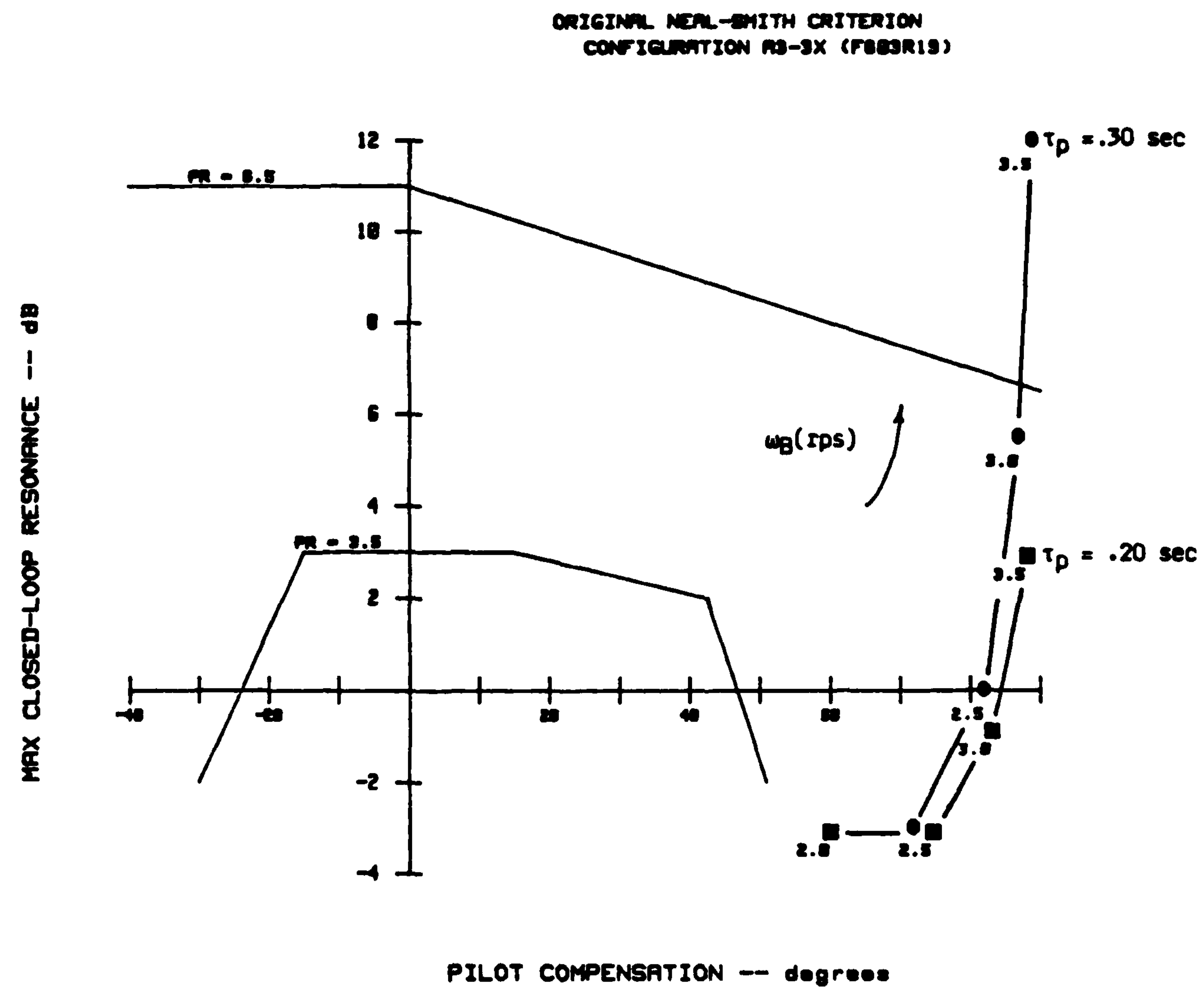


Figure F-3. NEAL SMITH PARAMETER PLANE, CONFIGURATION A3-3x

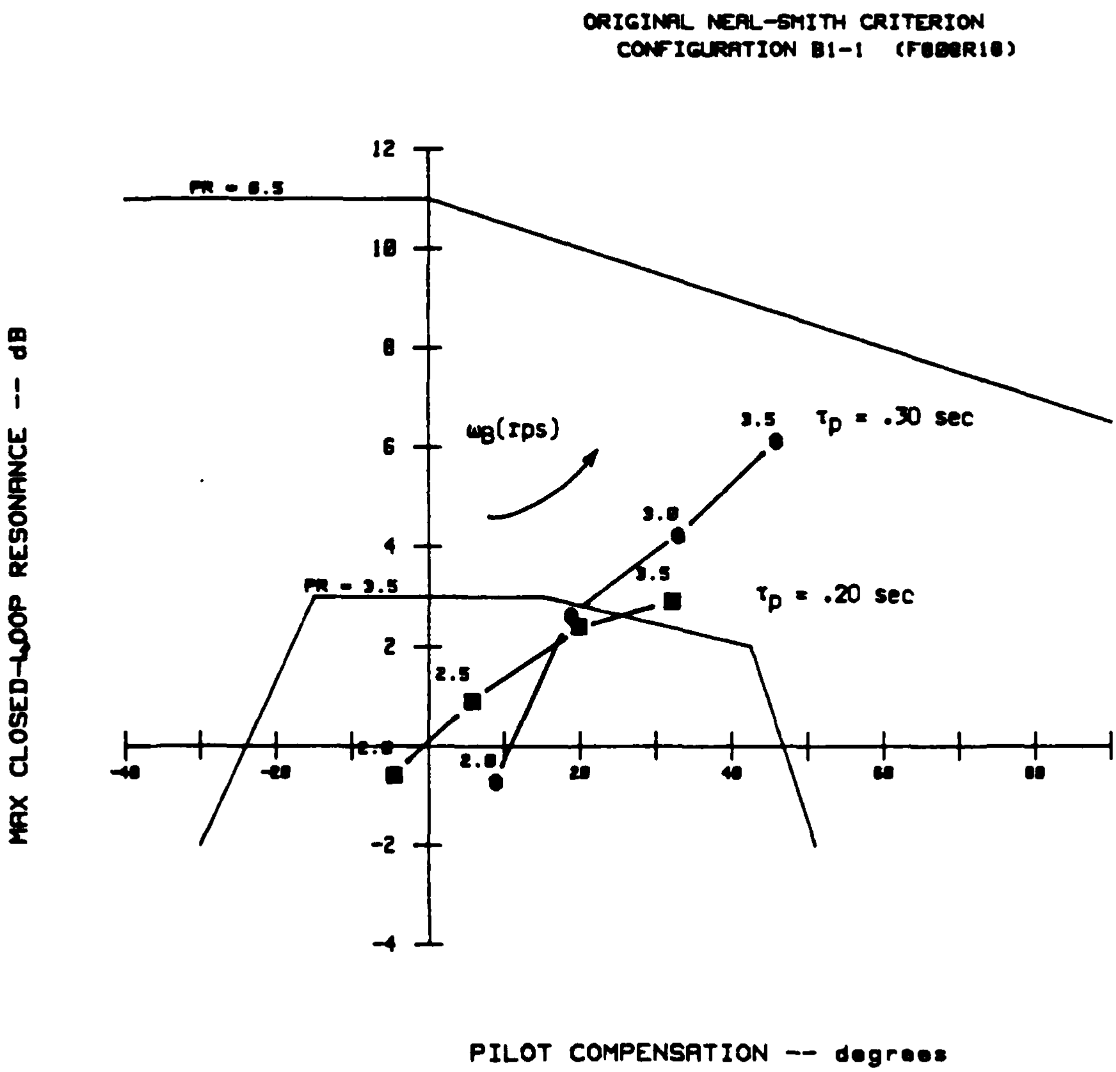


Figure F-4. NEAL SMITH PARAMETER PLANE, CONFIGURATION B1-1

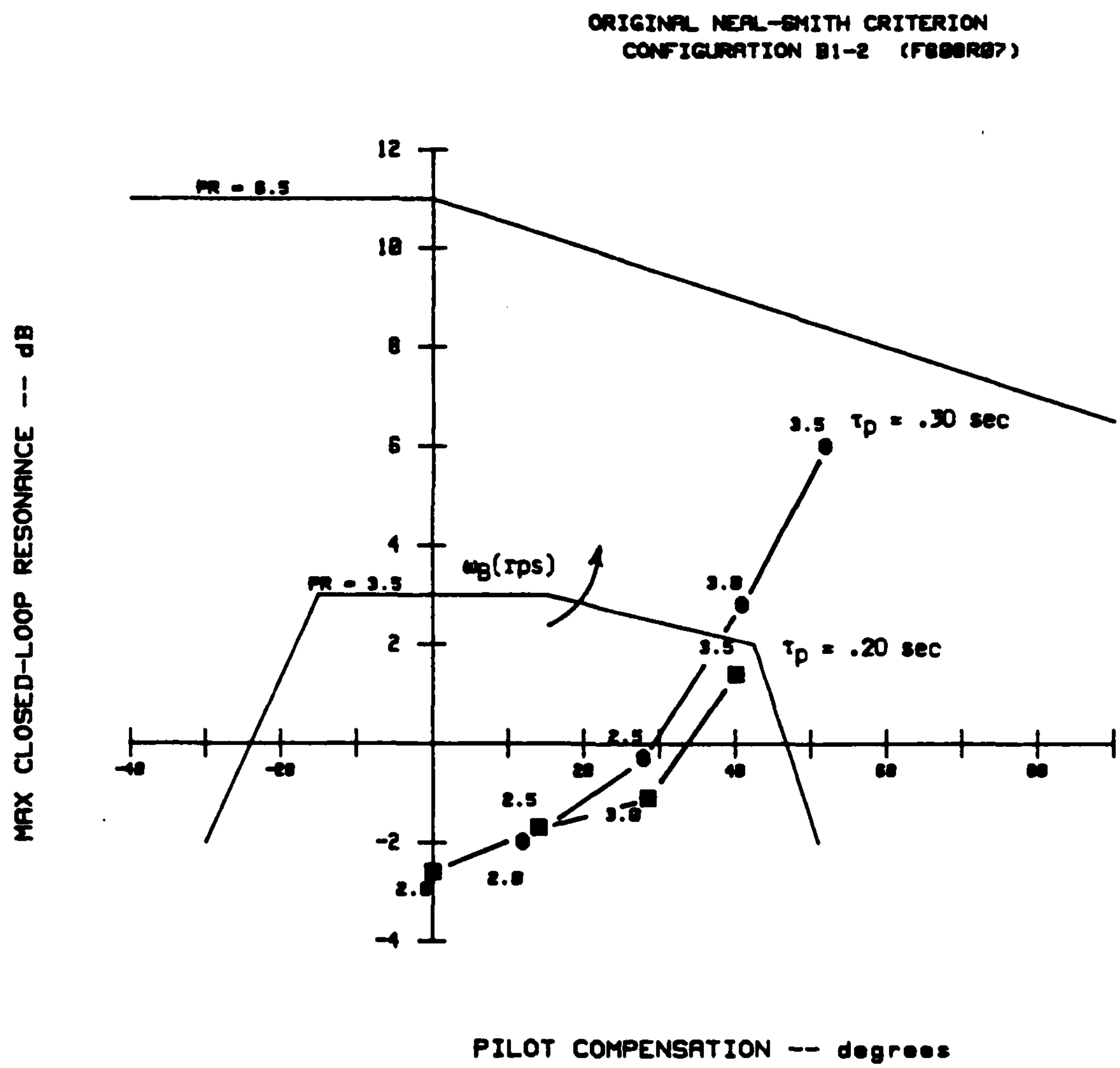


Figure F-5. NEAL SMITH PARAMETER PLANE, CONFIGURATION B1-2

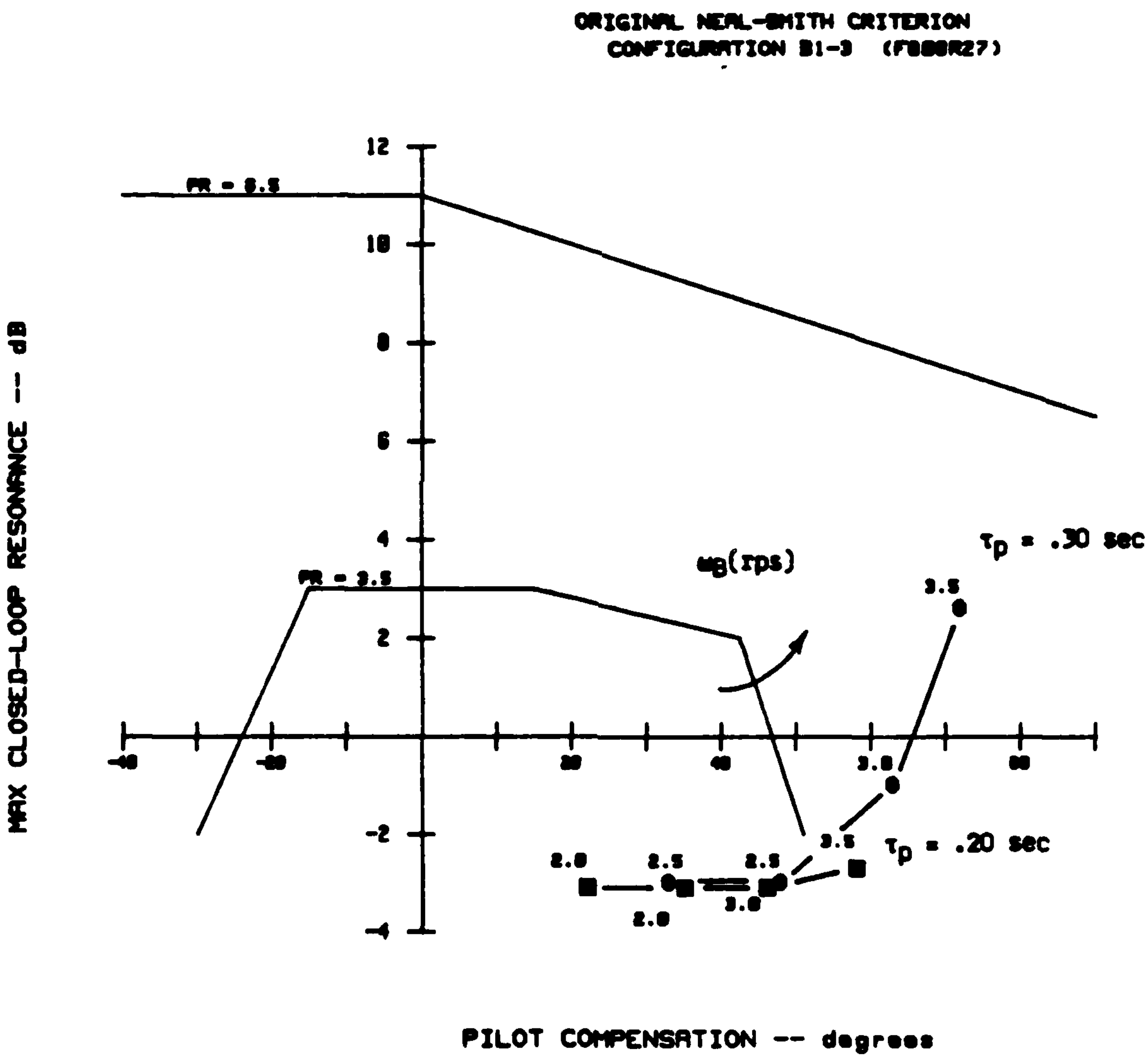


Figure F-6. NEAL SMITH PARAMETER PLANE, CONFIGURATION B1-3

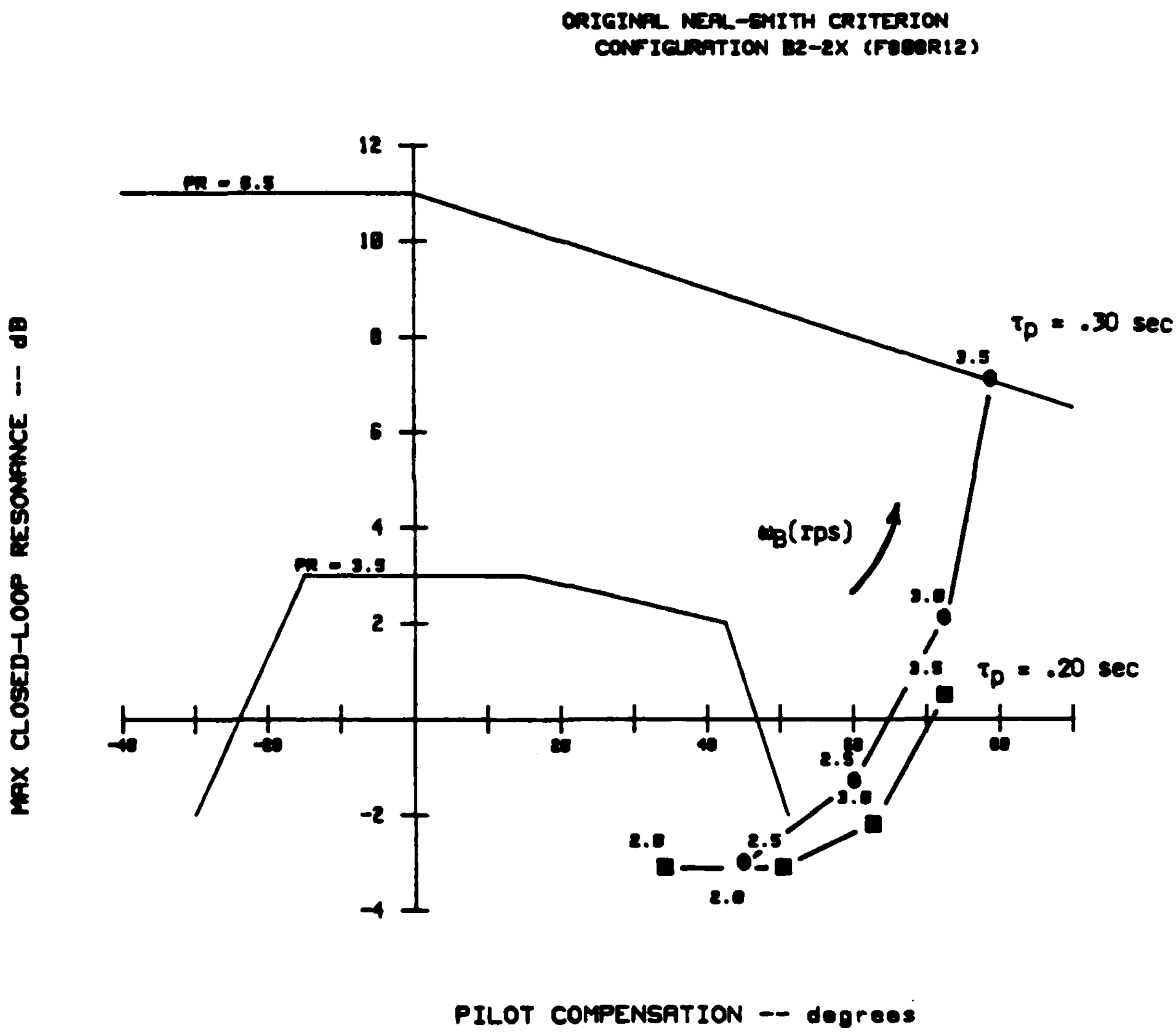


Figure F-7. NEAL SMITH PARAMETER PLANE, CONFIGURATION B2-2

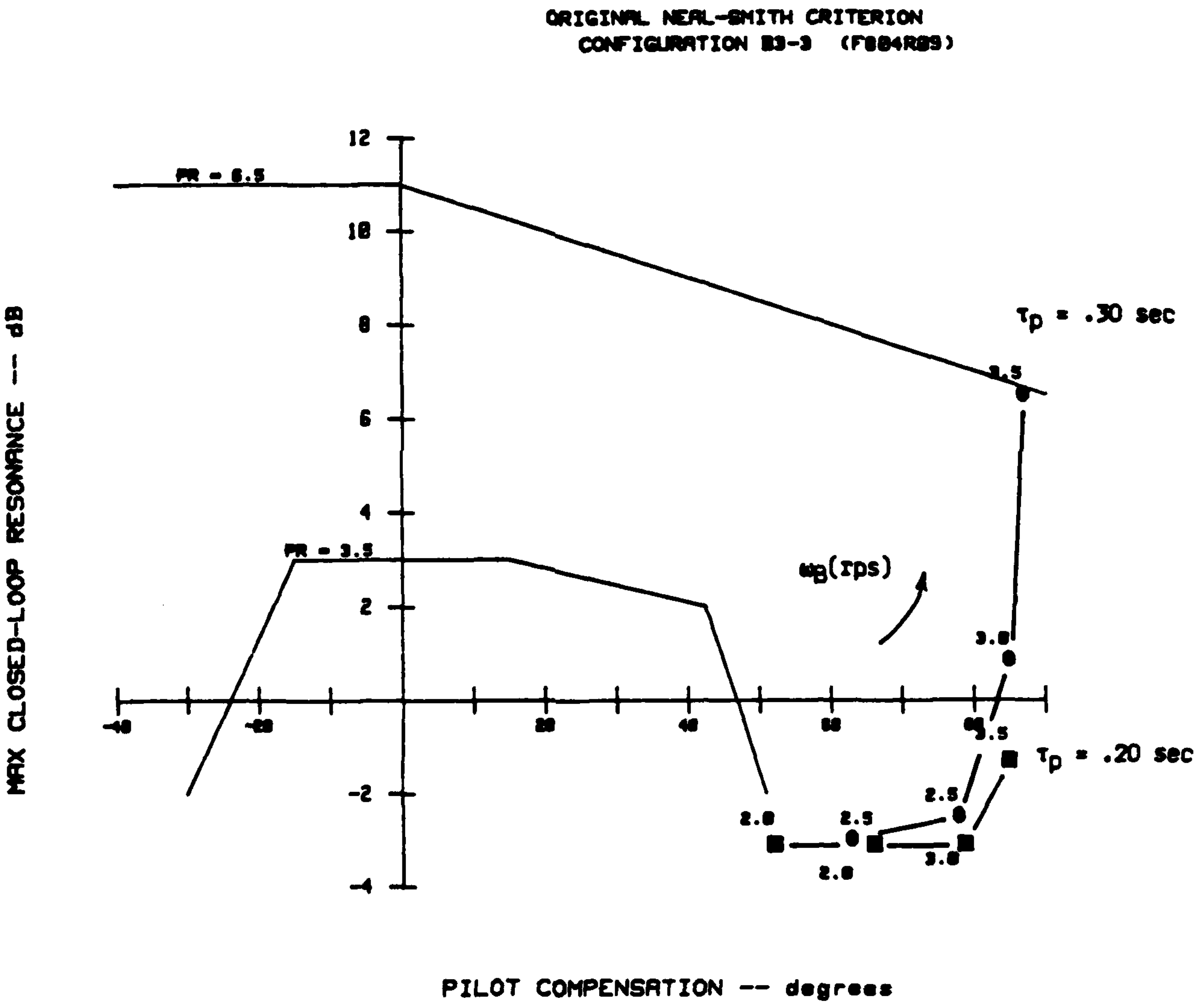


Figure F-8. NEAL SMITH PARAMETER PLANE, CONFIGURATION B3-3

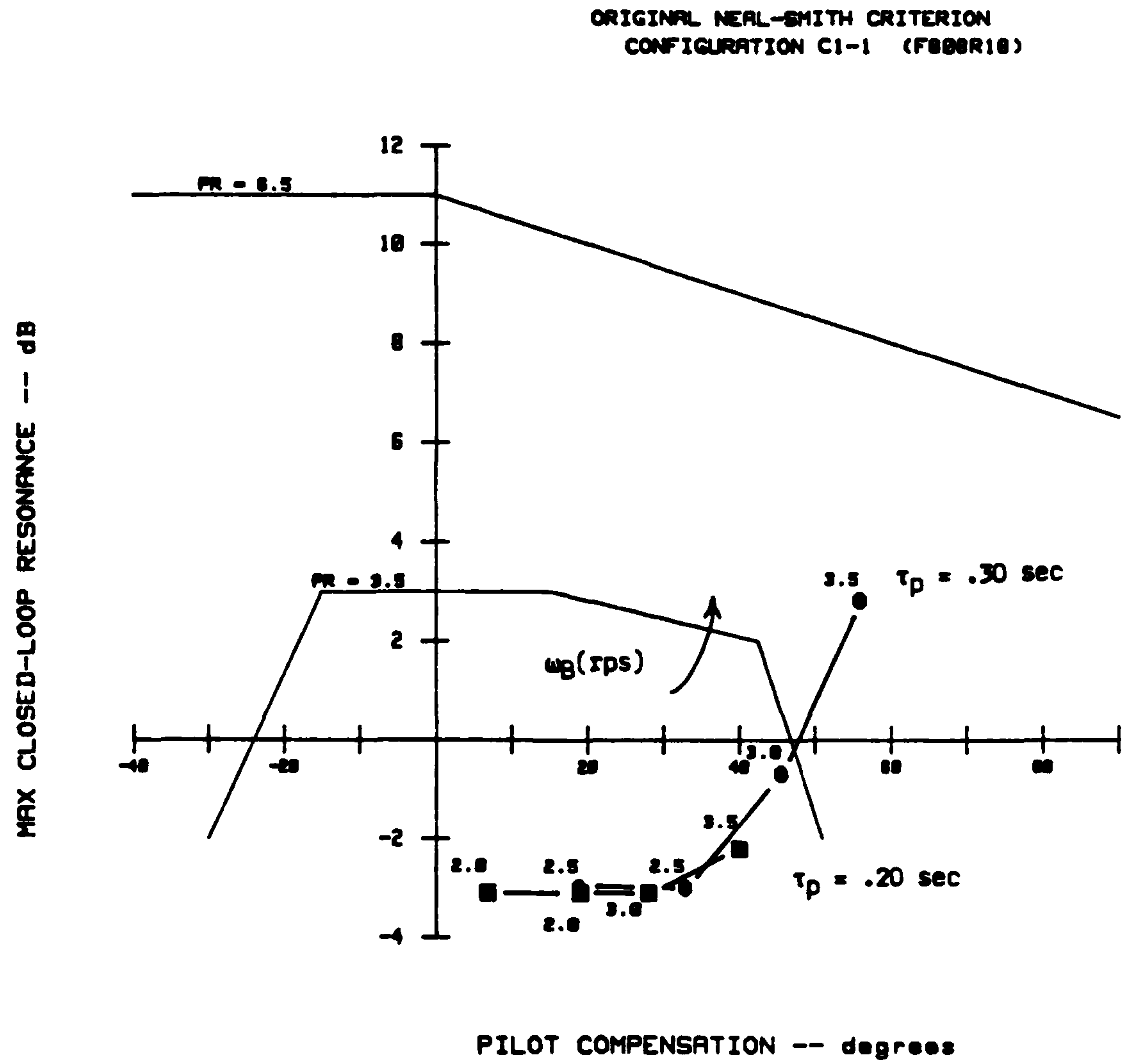


Figure F-9. NEAL SMITH PARAMETER PLANE, CONFIGURATION C1-1

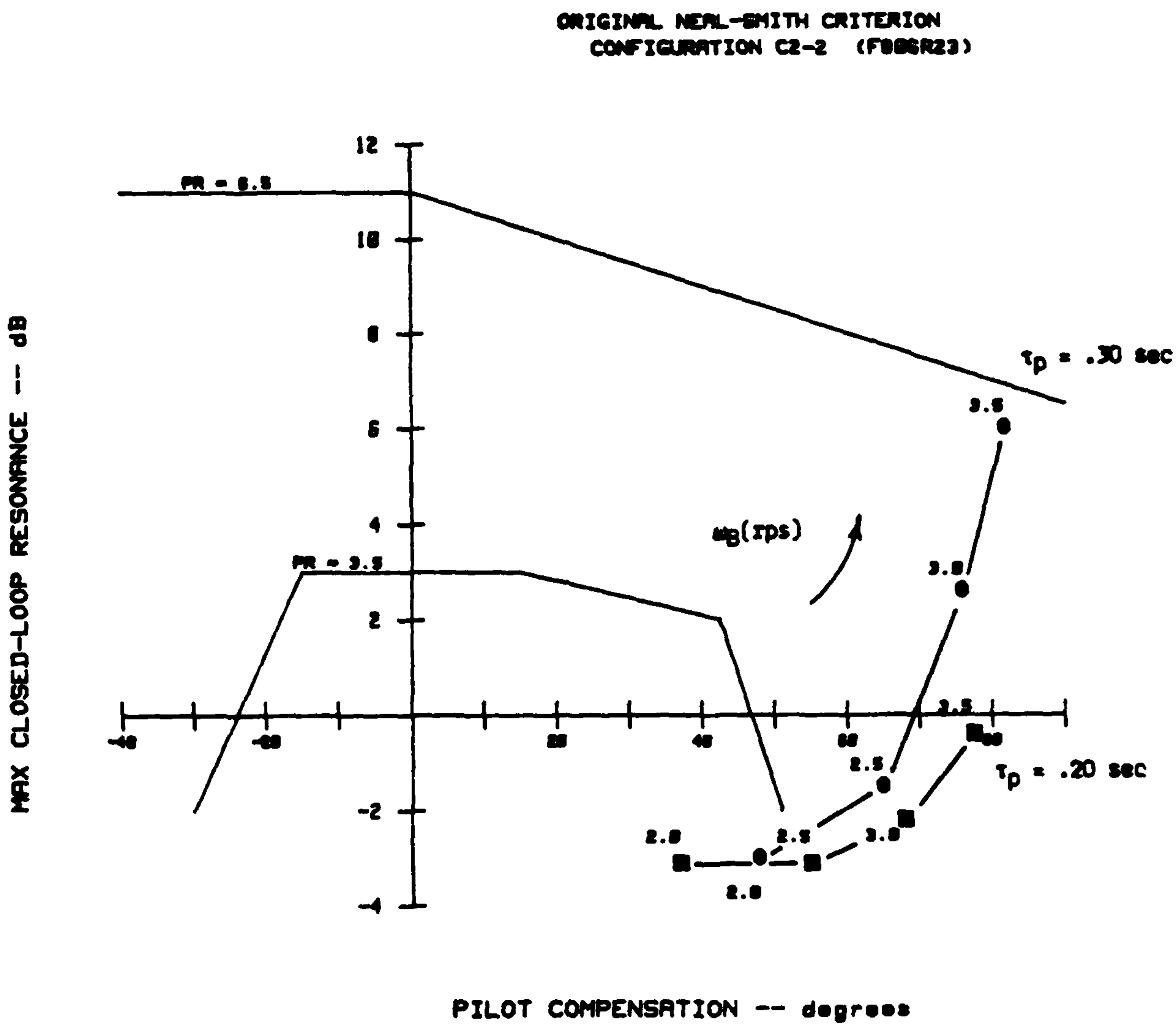


Figure F-10. NEAL-SMITH PARAMETER PLANE, CONFIGURATION C2-2

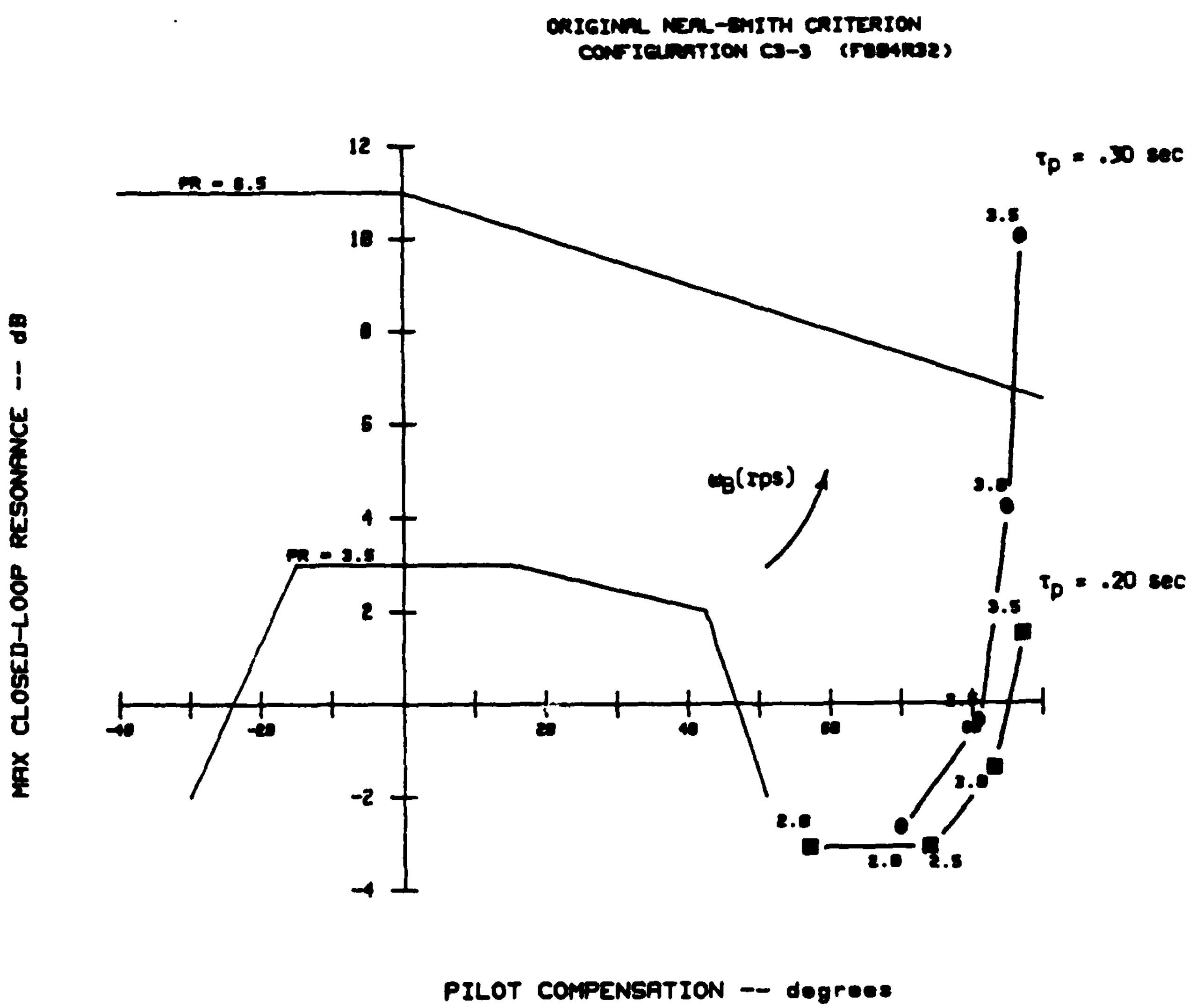


Figure F-11. NEAL-SMITH PARAMETER PLANE, CONFIGURATION C3-3

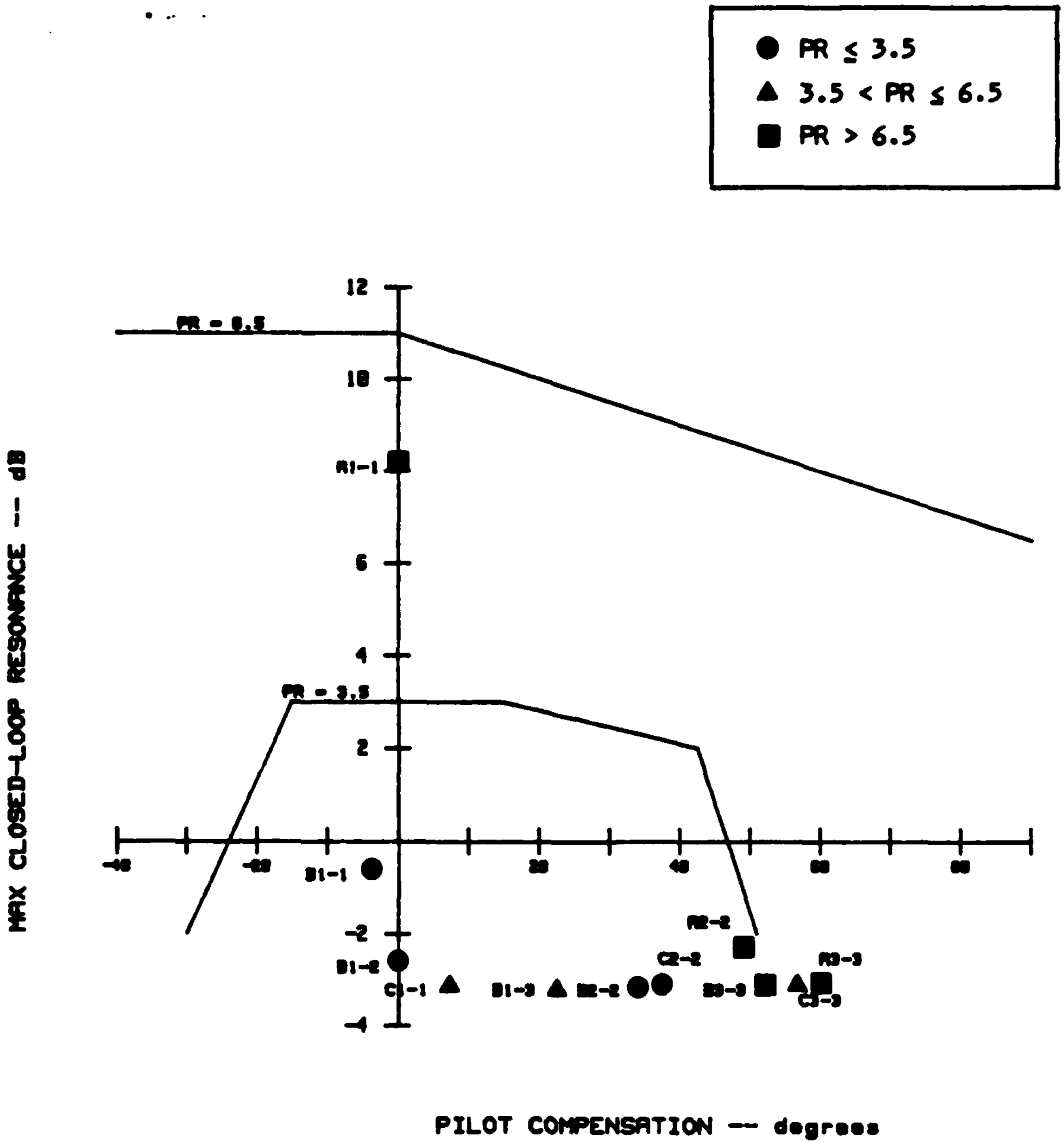


Figure F-12. NEAL SMITH CRITERION, BANDWIDTH: 2.0 r/s; PILOT DELAY: .2 sec

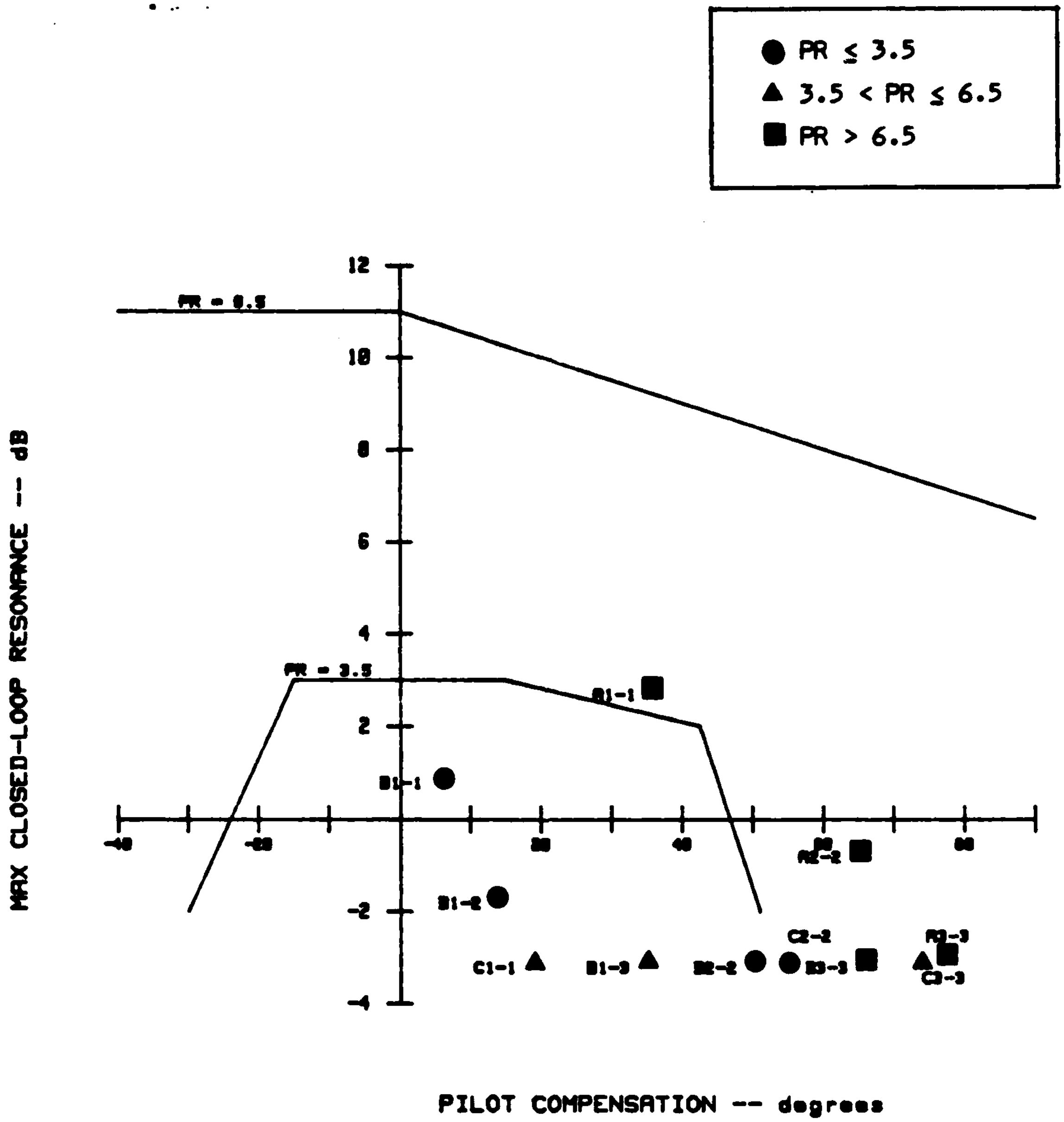


Figure F-13. NEAL SMITH CRITERION, BANDWIDTH: 2.5 r/s; PILOT DELAY: .2 sec

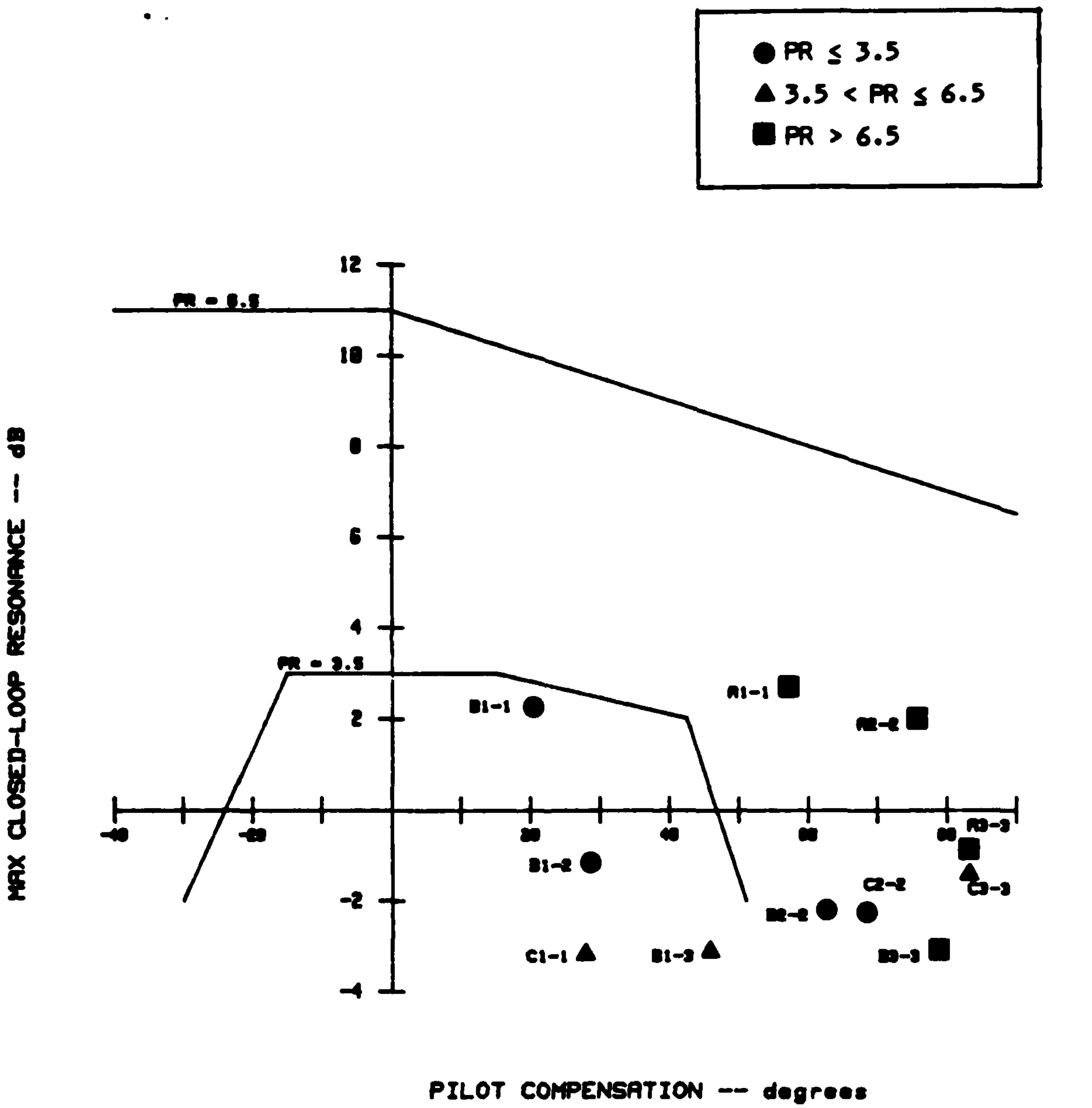


Figure F-14. NEAL SMITH CRITERION, BANDWIDTH: 3.0 r/s; PILOT DELAY: .2 sec

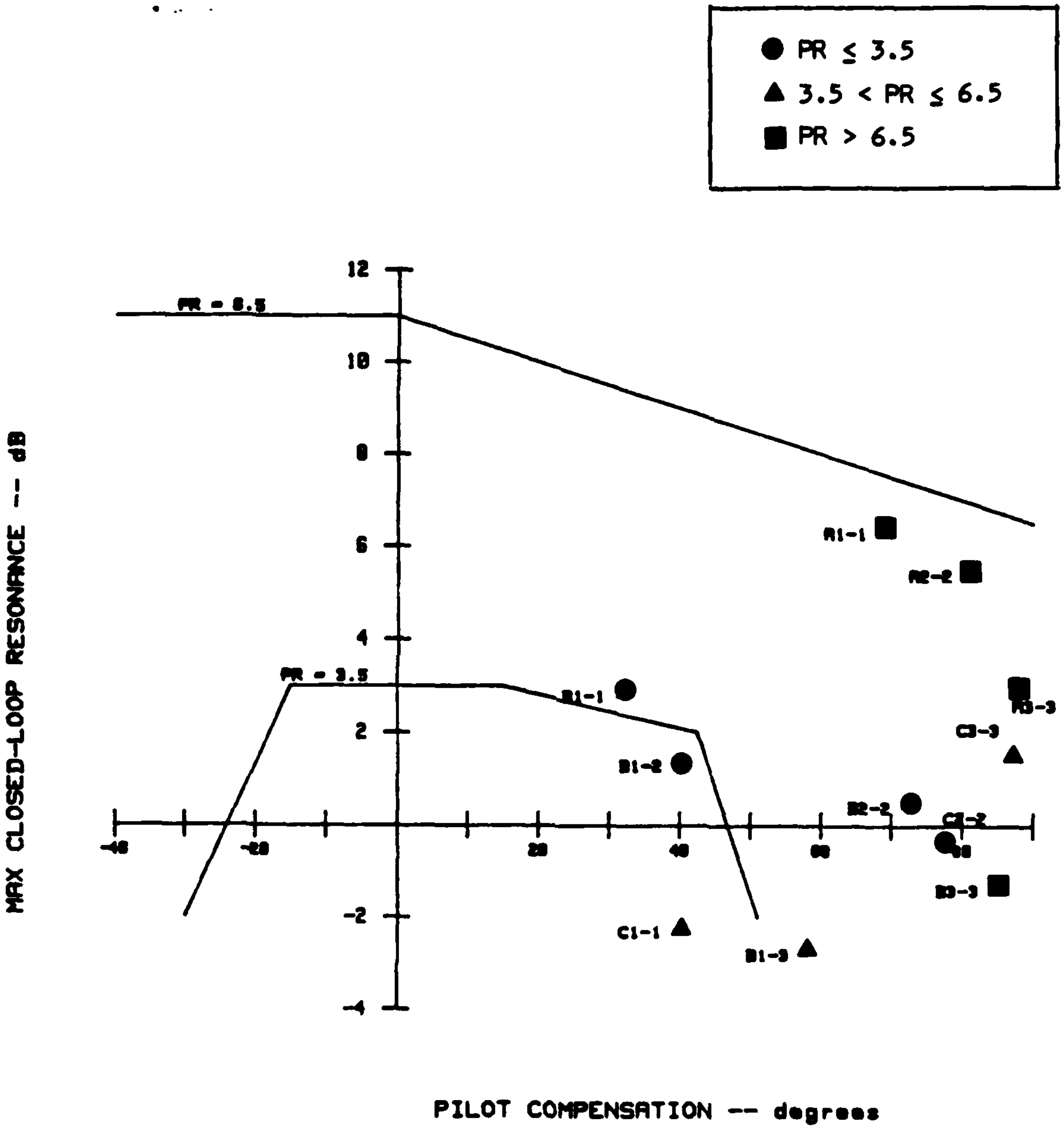


Figure F-15. NEAL SMITH CRITERION, BANDWIDTH: 3.5 r/s; PILOT DELAY: .2 sec

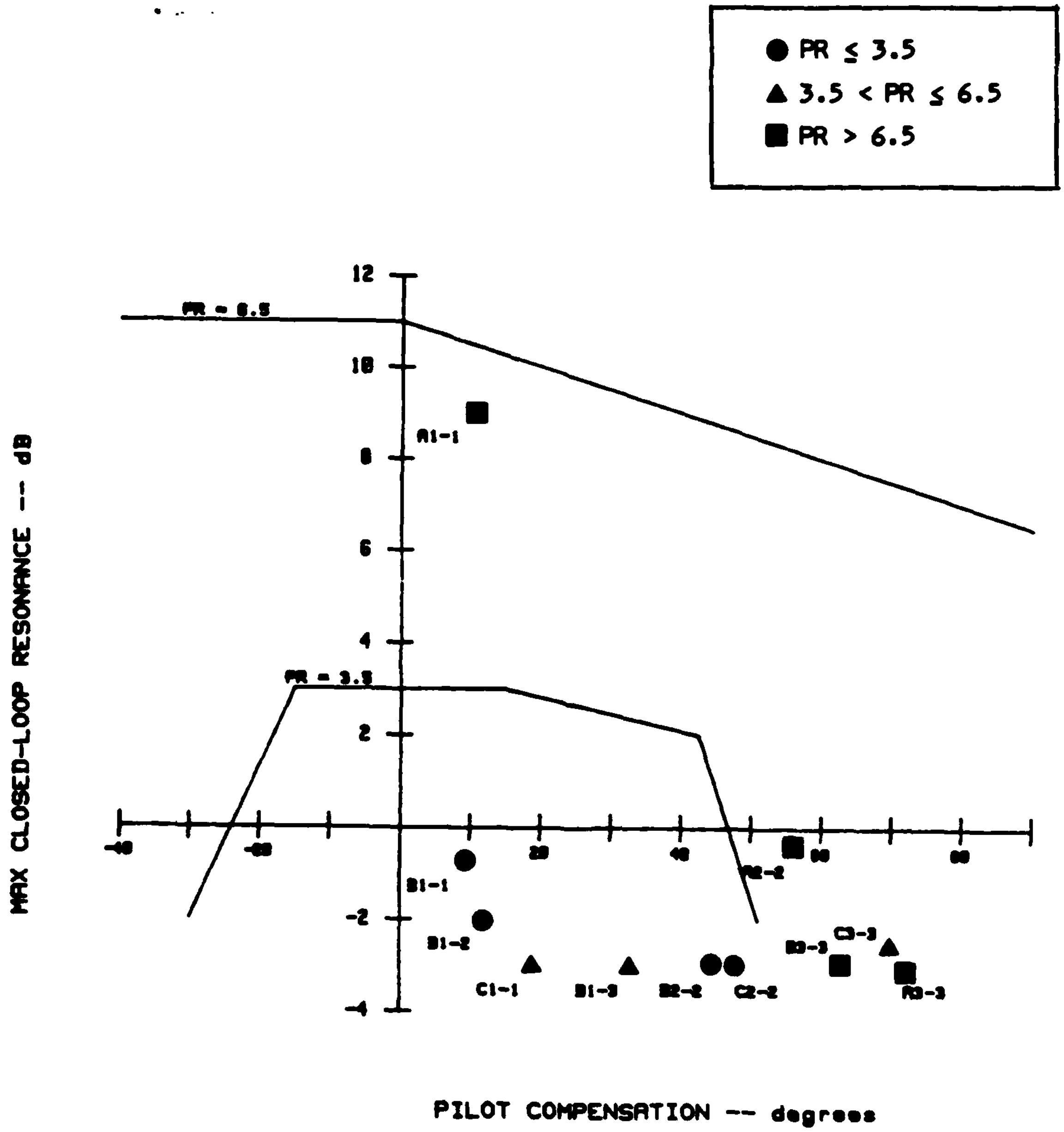


Figure F-16. NEAL SMITH CRITERION, BANDWIDTH: 2.0 r/s; PILOT DELAY: .3 sec

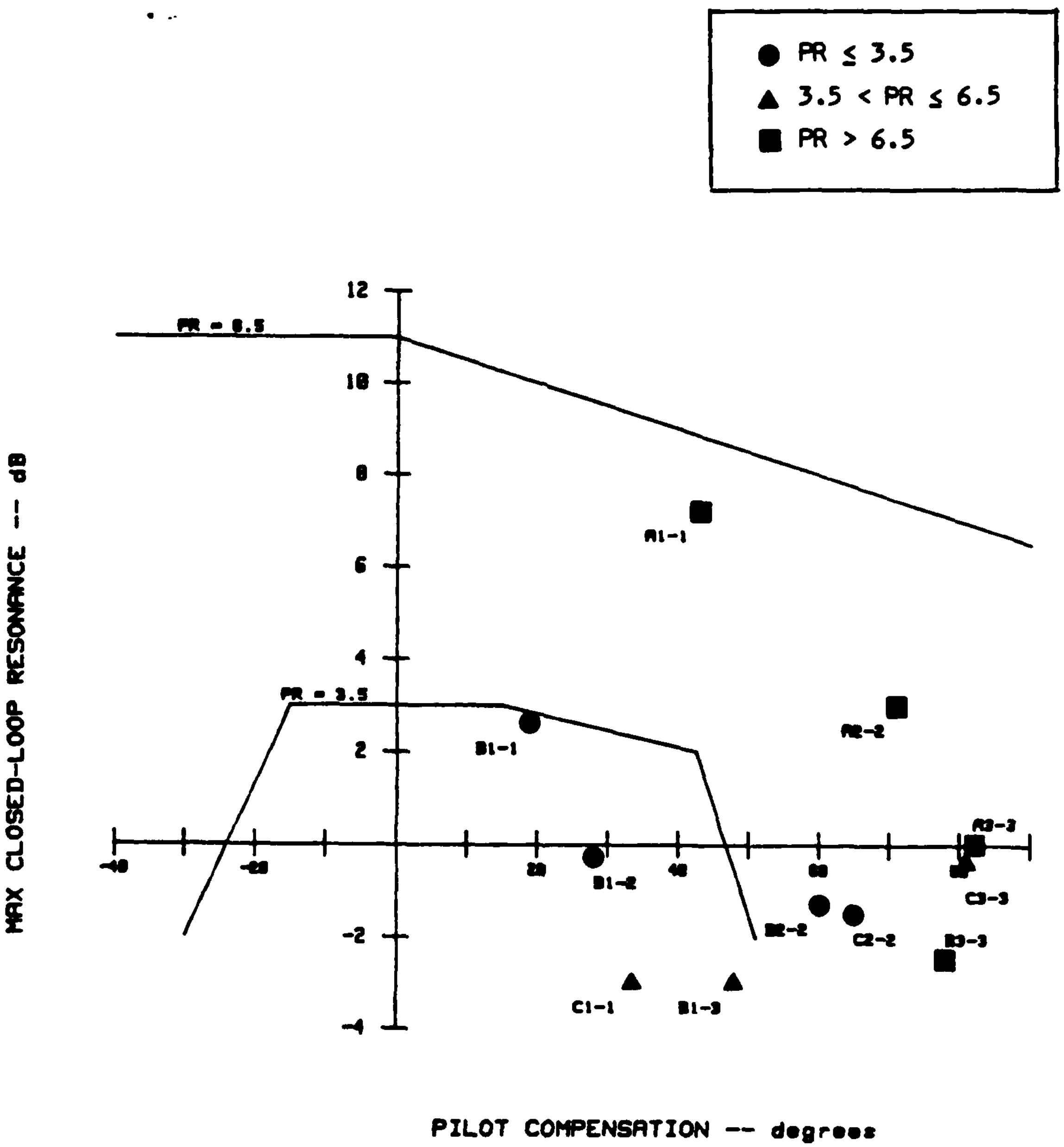


Figure F-17. NEAL SMITH CRITERION, BANDWIDTH: 2.5 r/s; PILOT DELAY: .3 sec

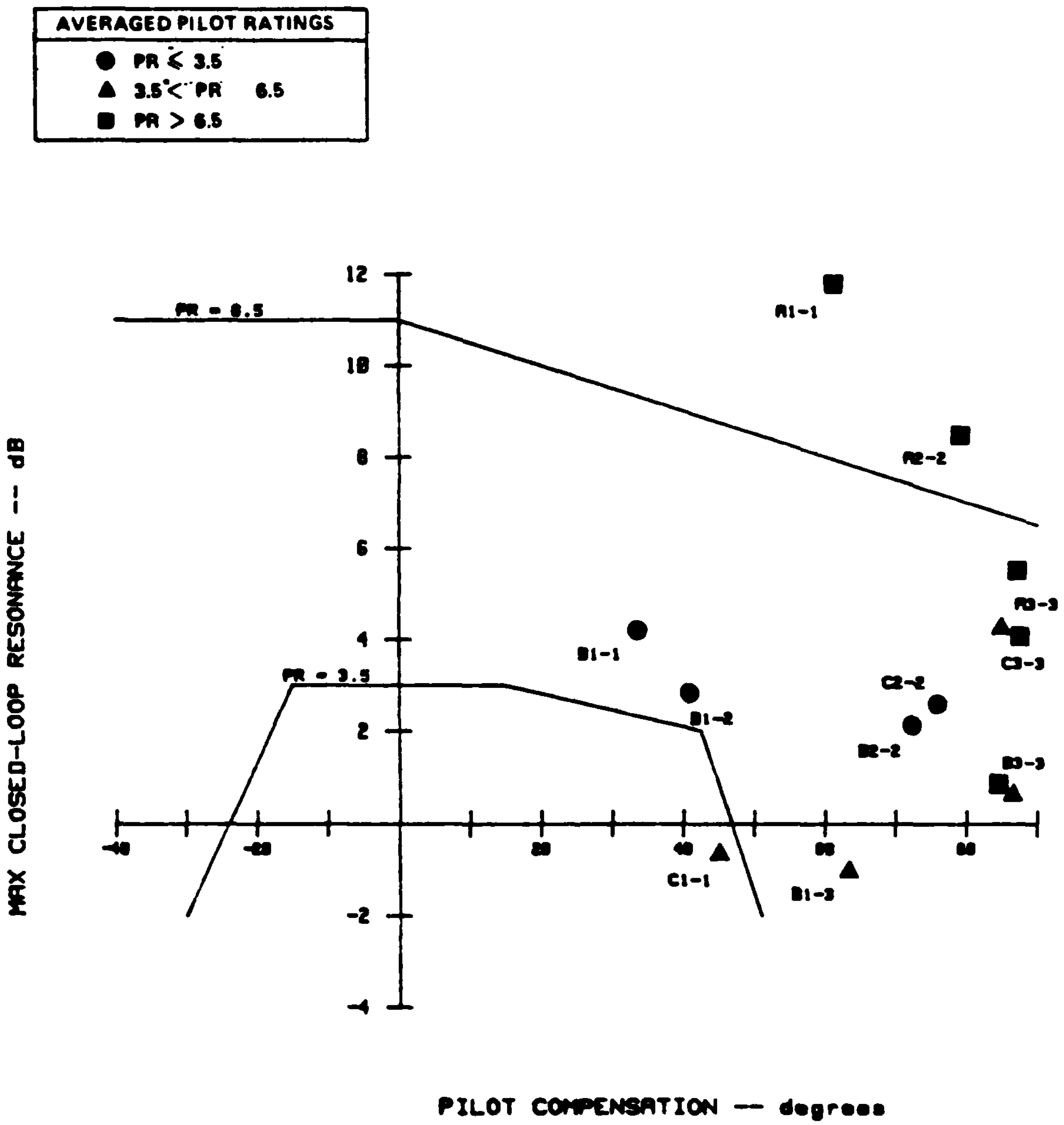


Figure F-18. NEAL SMITH CRITERION, BANDWIDTH: 3.0 r/s; PILOT DELAY: .3 sec

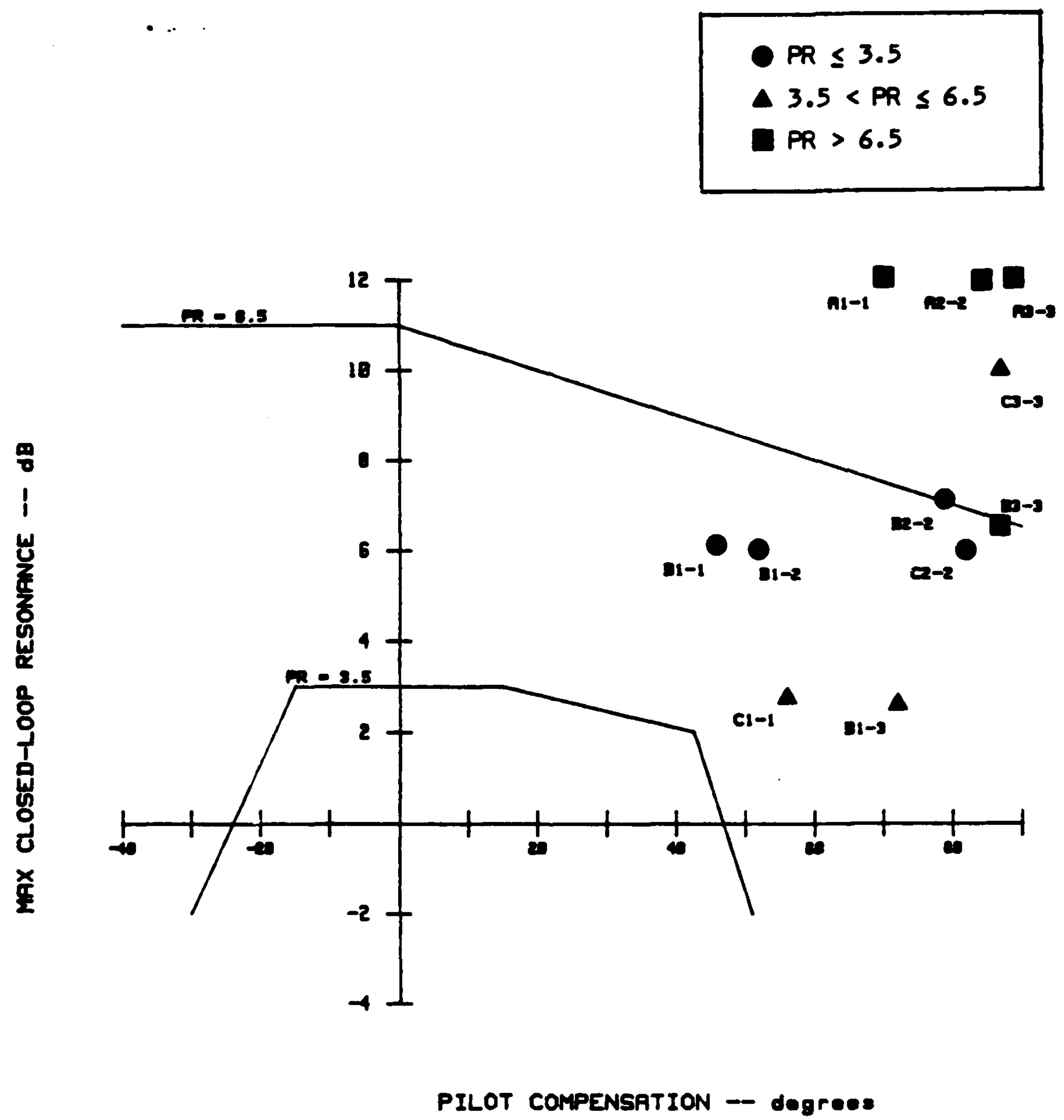


Figure F-19. NEAL SMITH CRITERION, BANDWIDTH: 3.5 r/s; PILOT DELAY: .3 sec

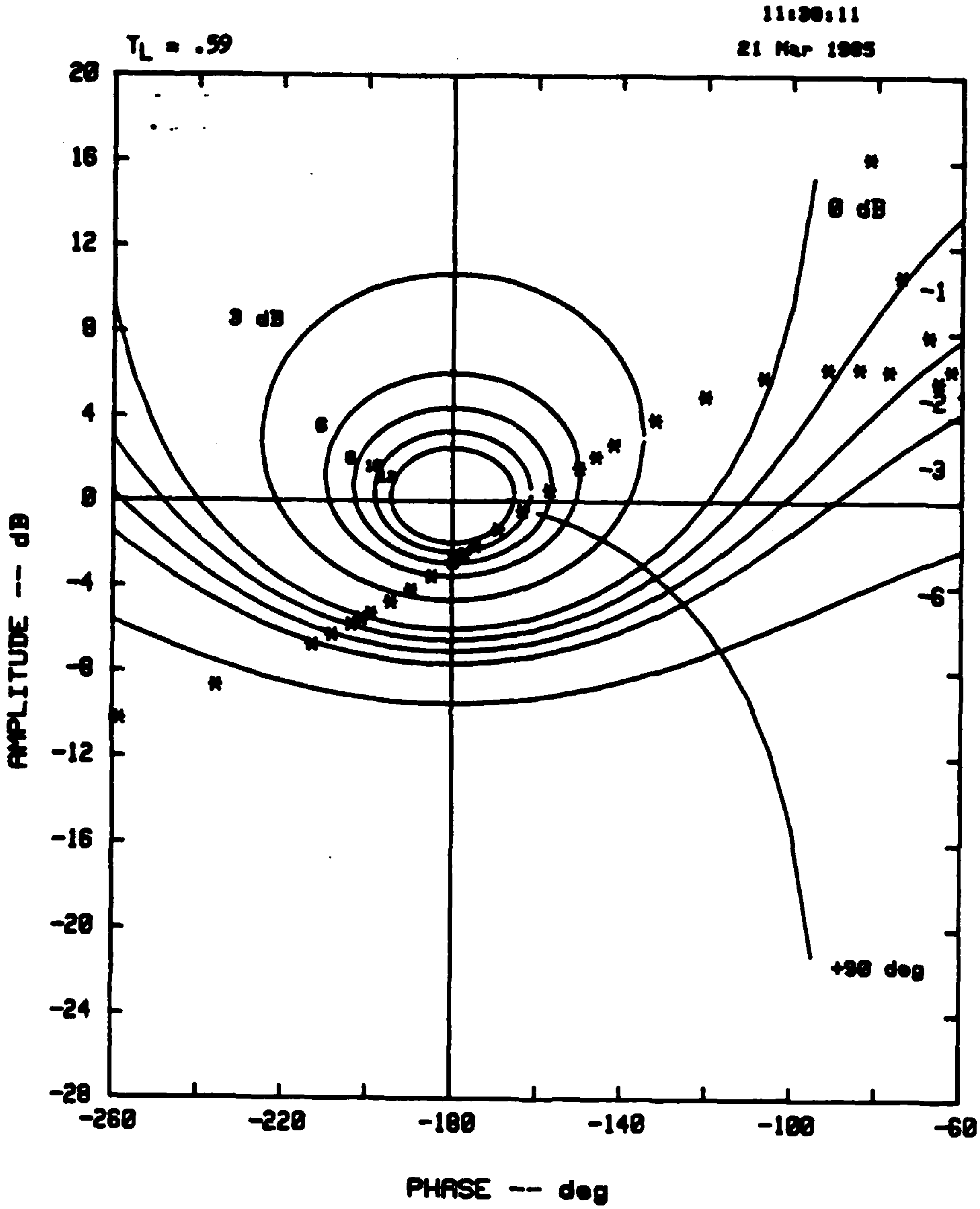


Figure F-20. NICHOLS CHART, CONFIGURATION A1-1, CLOSED LOOP BANDWIDTH: 3.0 r/s; PILOT TIME DELAY: .3 sec

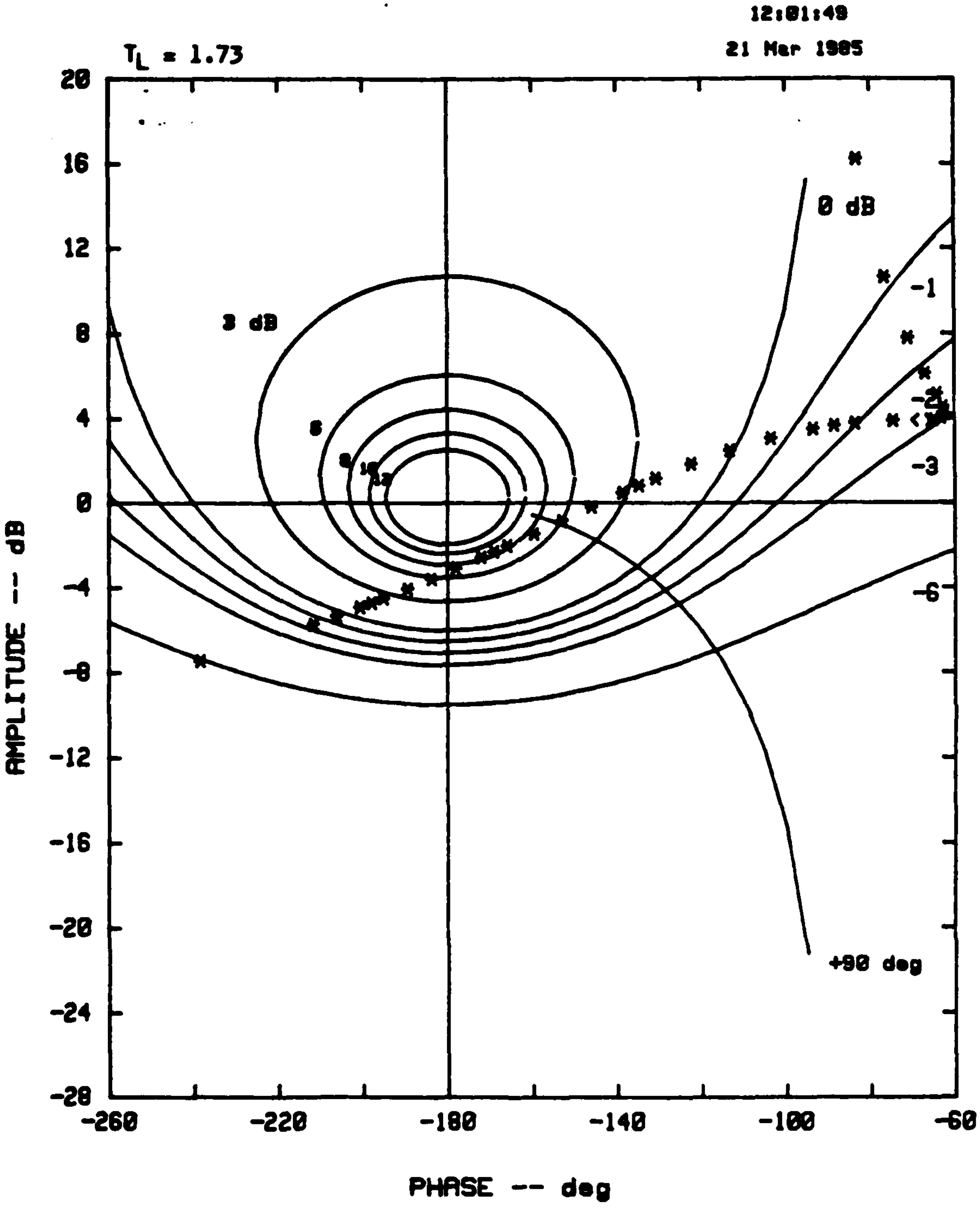


Figure F-21. NICHOLS CHART, CONFIGURATION A2-2x, CLOSED LOOP BANDWIDTH: 3.0 r/s; PILOT TIME DELAY: .3 sec

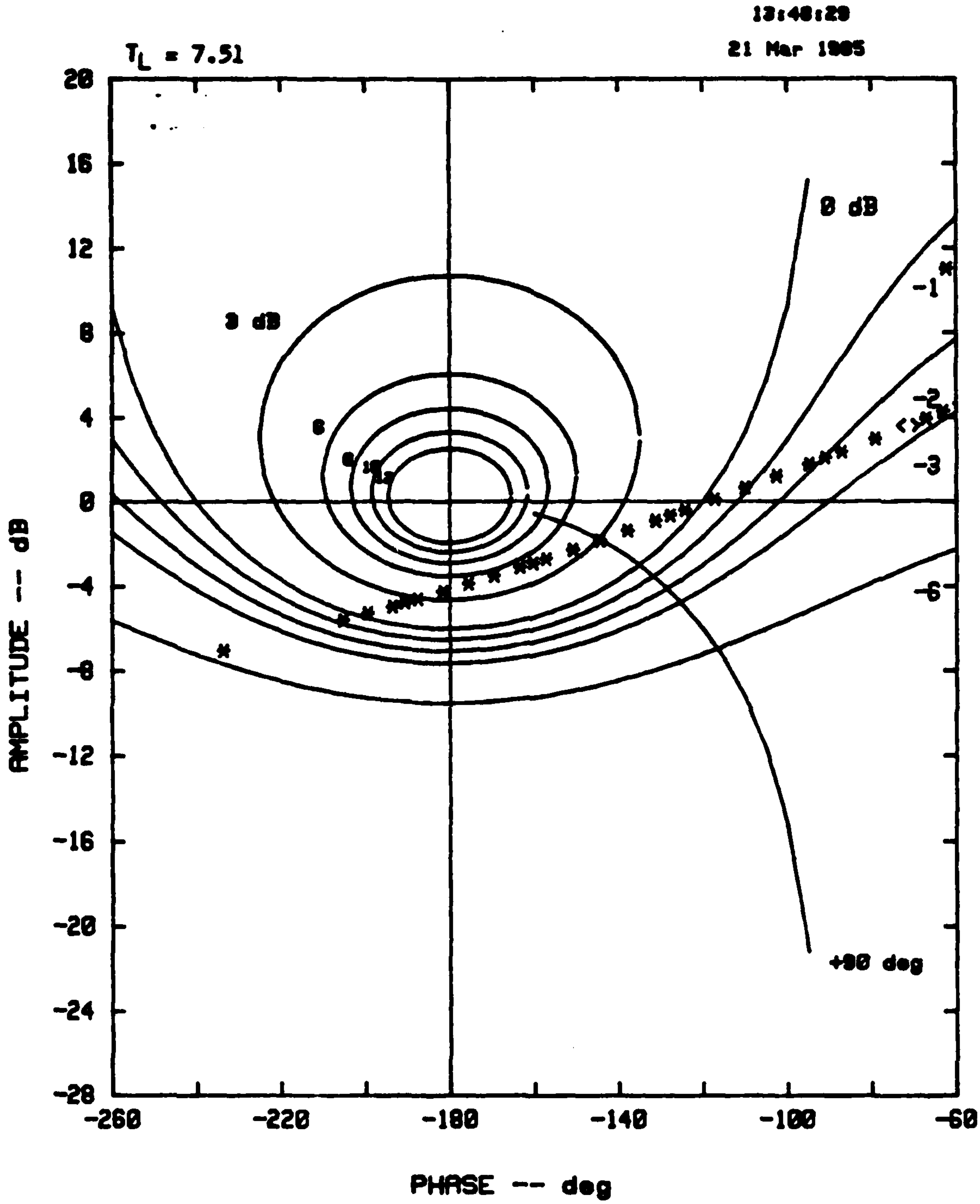


Figure F-22. NICHOLS CHART, CONFIGURATION A3-3x, CLOSED LOOP BANDWIDTH: 3.0 r/s; PILOT TIME DELAY: .3 sec

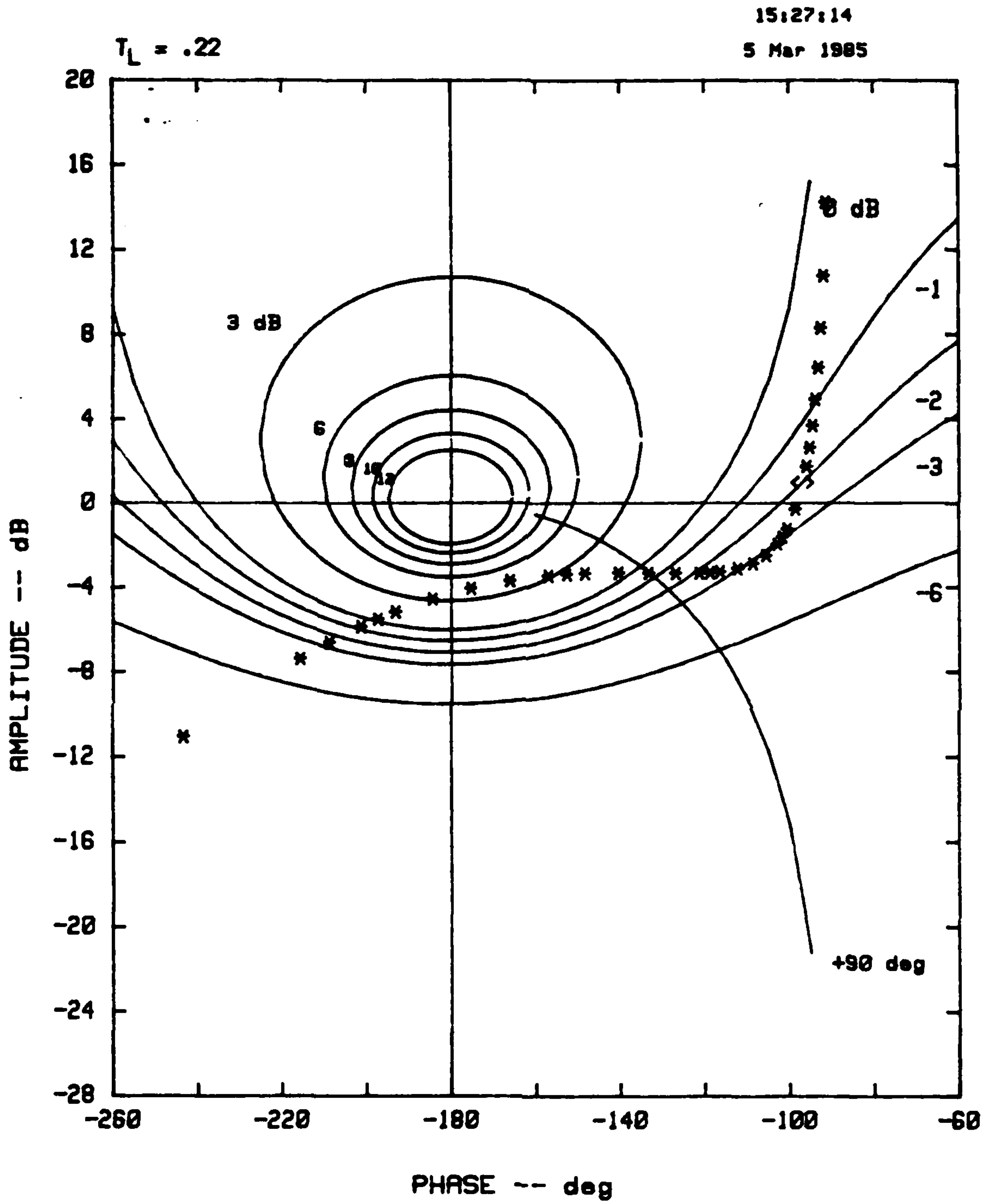


Figure F-23. NICHOLS CHART, CONFIGURATION B1-1, CLOSED LOOP BANDWIDTH: 3.0 r/s; PILOT TIME DELAY: .3 sec

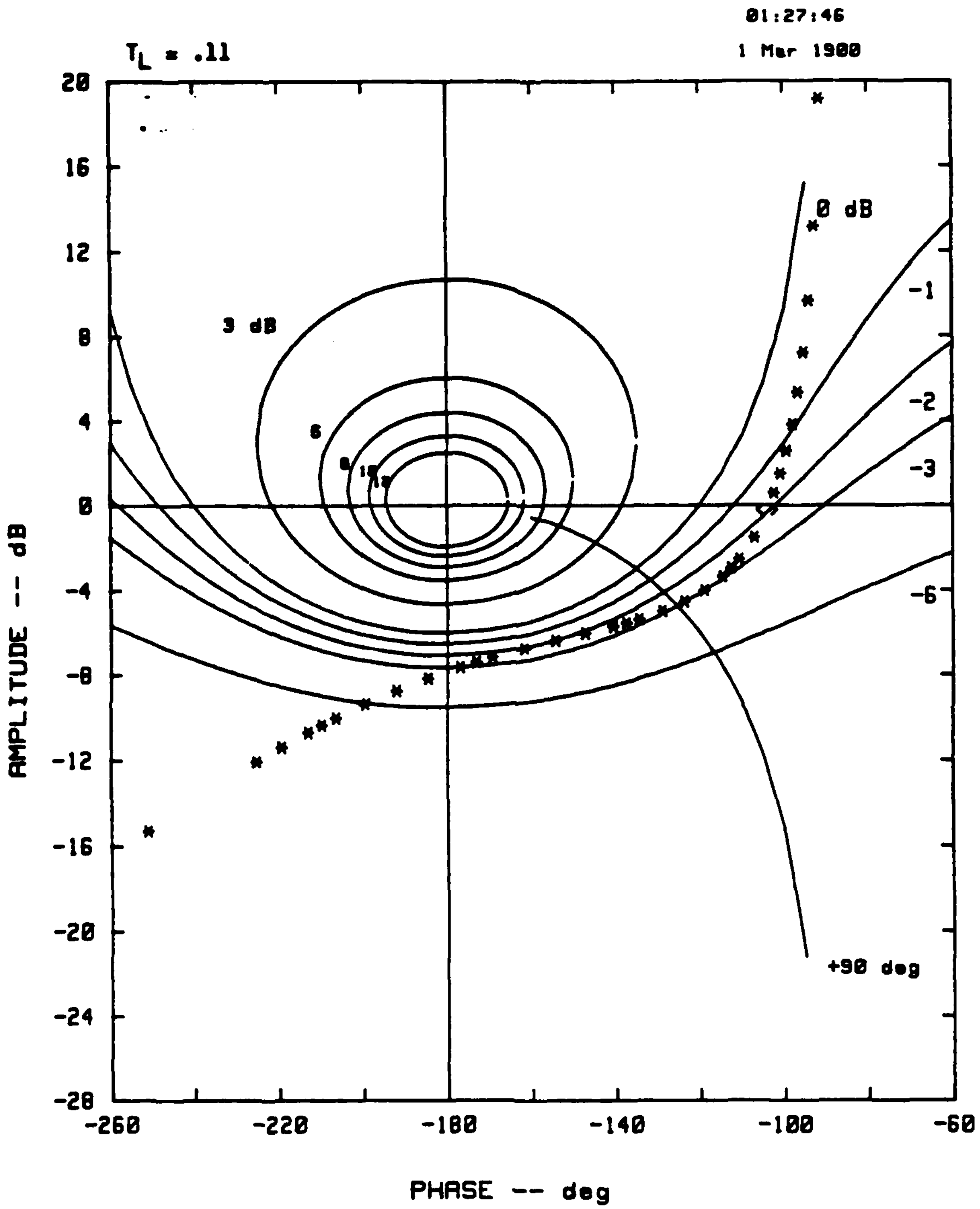


Figure F-24. NICHOLS CHART, CONFIGURATION B1-2, CLOSED LOOP BANDWIDTH: 3.0 r/s; PILOT TIME DELAY: .3 sec

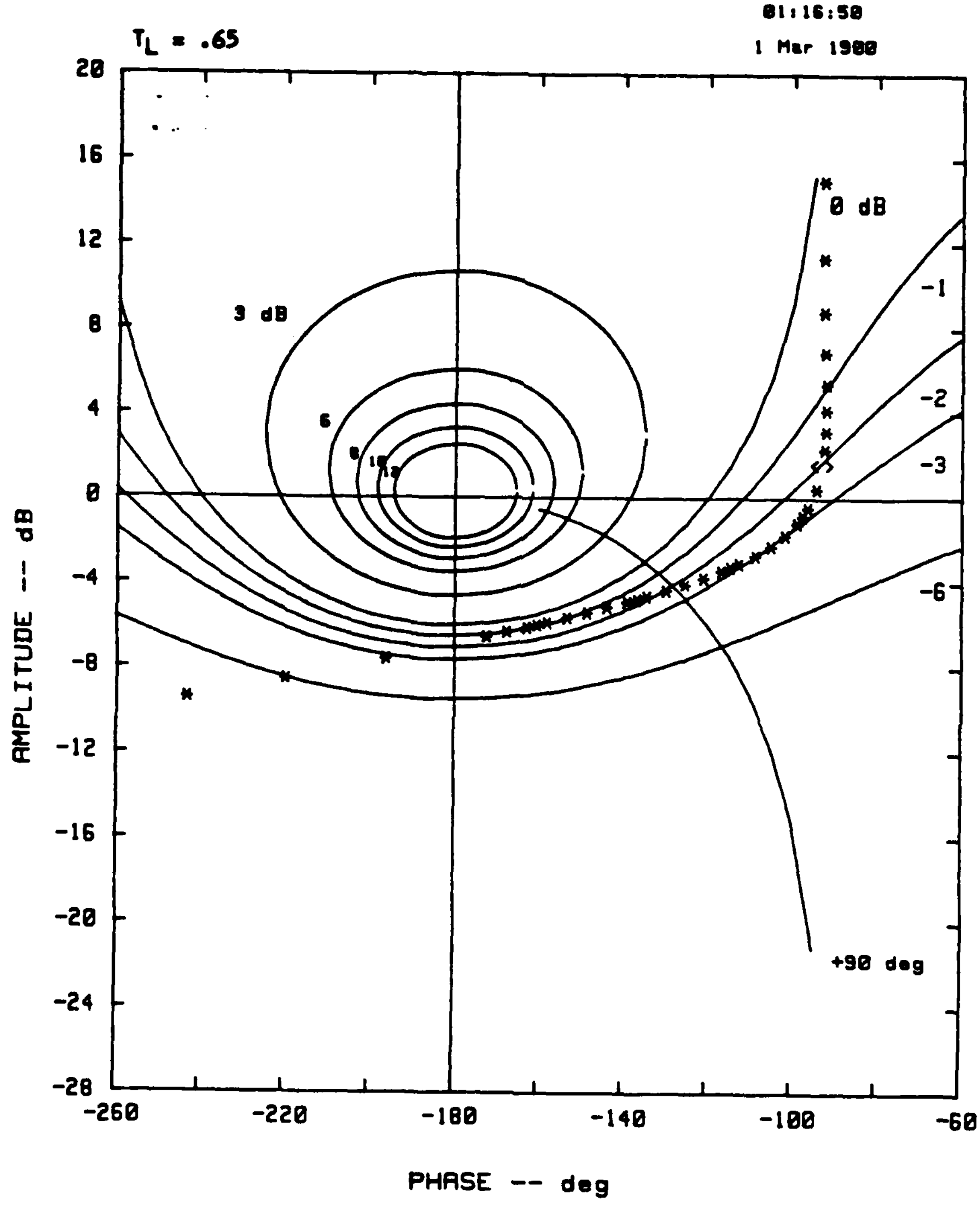


Figure F-25. NICHOLS CHART, CONFIGURATION B1-3, CLOSED LOOP BANDWIDTH: 3.0 r/s; PILOT TIME DELAY: .3 sec

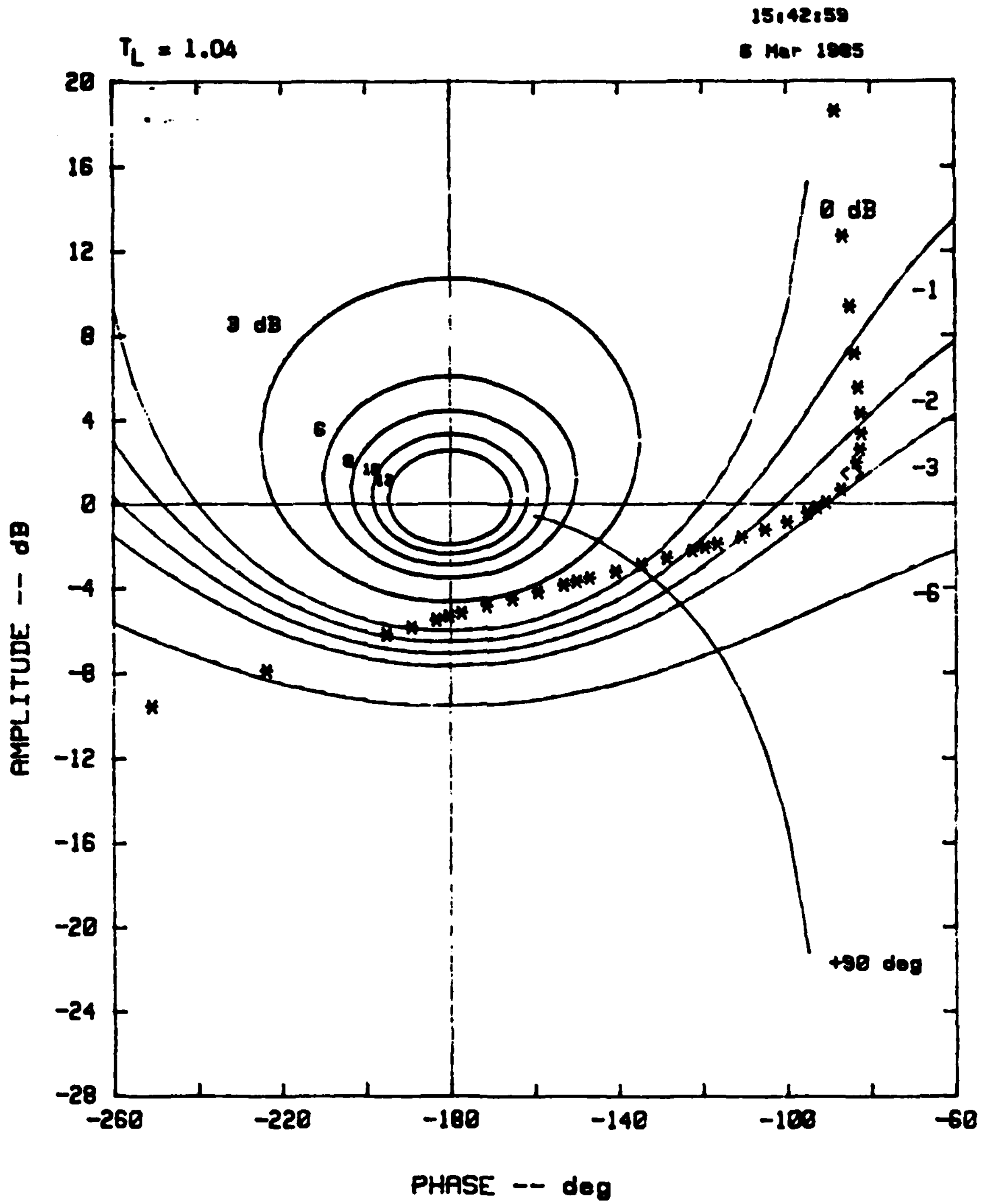


Figure F-26. NICHOLS CHART, CONFIGURATION B2-2x, CLOSED LOOP BANDWIDTH: 3.0 r/s; PILOT TIME DELAY: .3 sec

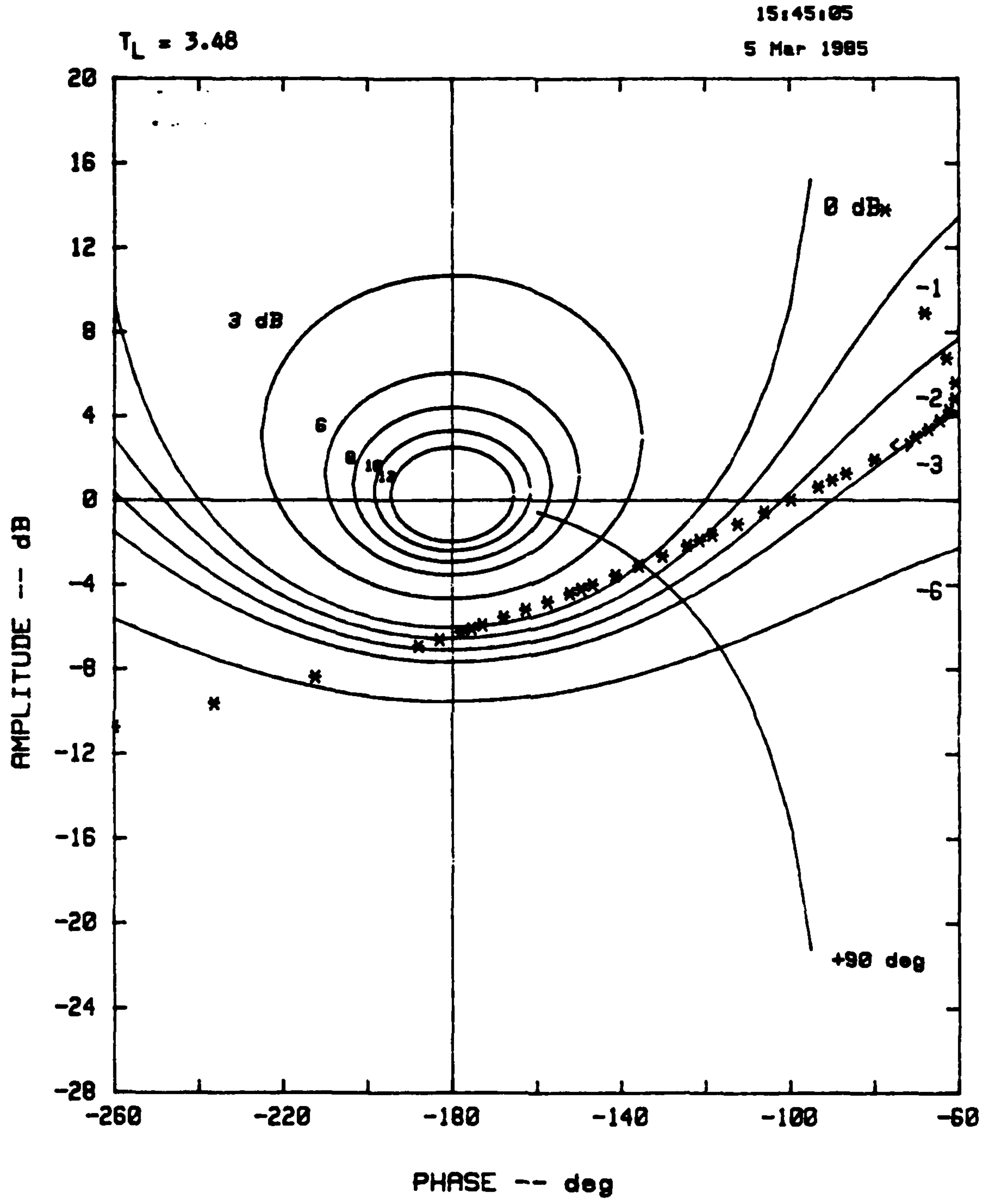


Figure F-27. NICHOLS CHART, CONFIGURATION B3-3, CLOSED LOOP BANDWIDTH: 3.0 r/s; PILOT TIME DELAY: .3 sec

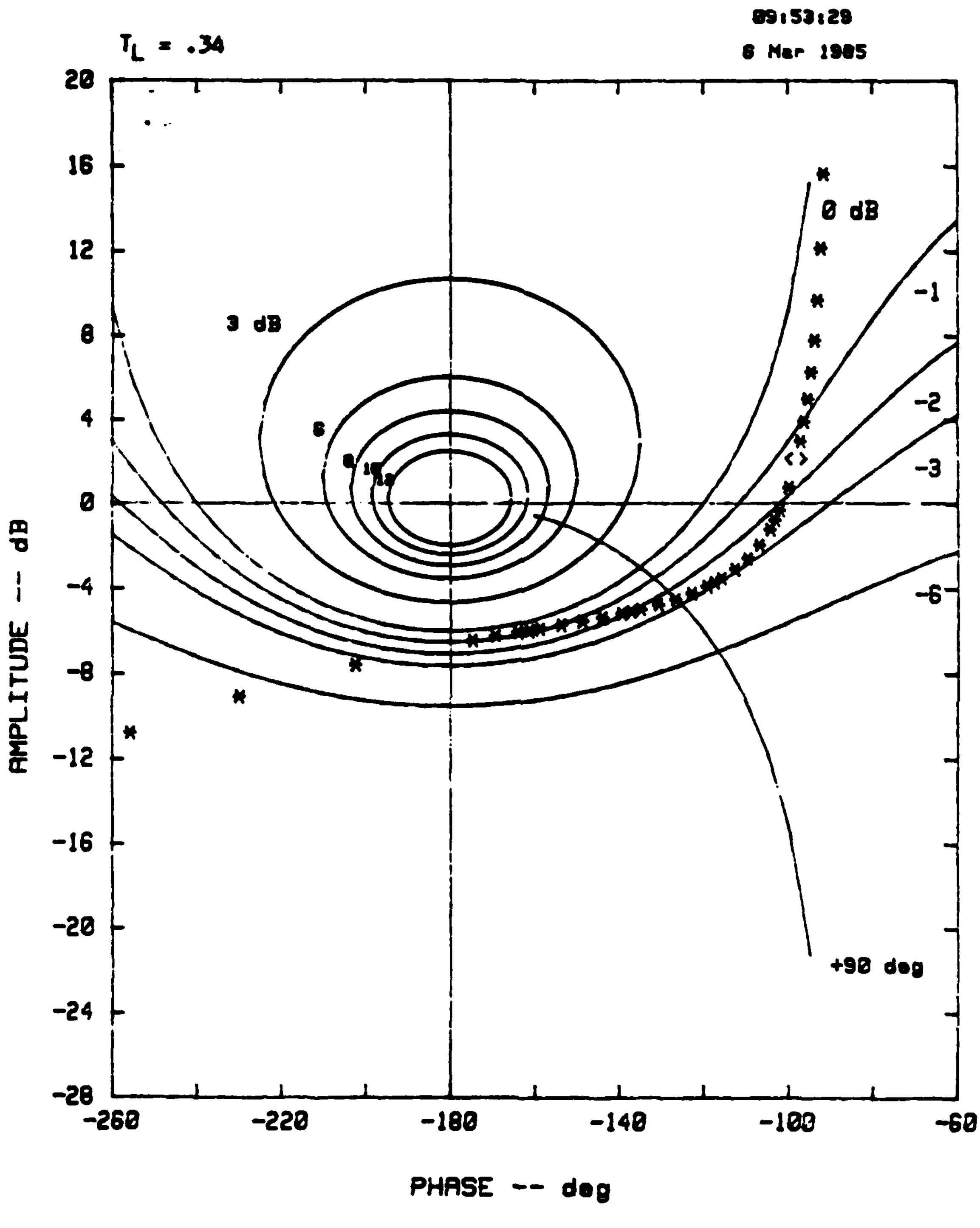


Figure F-28. NICHOLS CHART, CONFIGURATION C1-1, CLOSED LOOP BANDWIDTH: 3.0 r/s; PILOT TIME DELAY: .3 sec

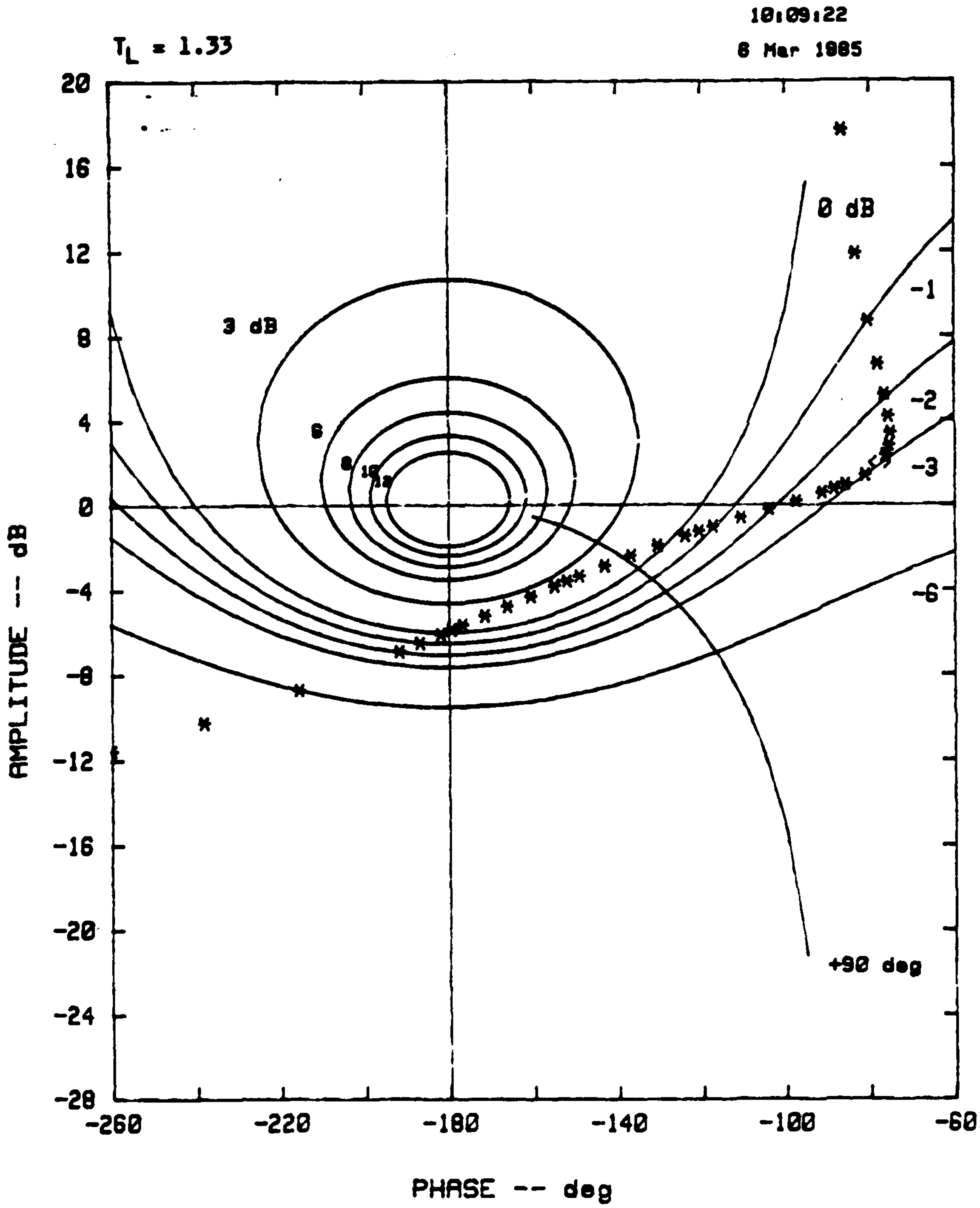


Figure F-29. NICHOLS CHART, CONFIGURATION C2-2, CLOSED LOOP BANDWIDTH: 3.0 r/s; PILOT TIME DELAY: .3 sec

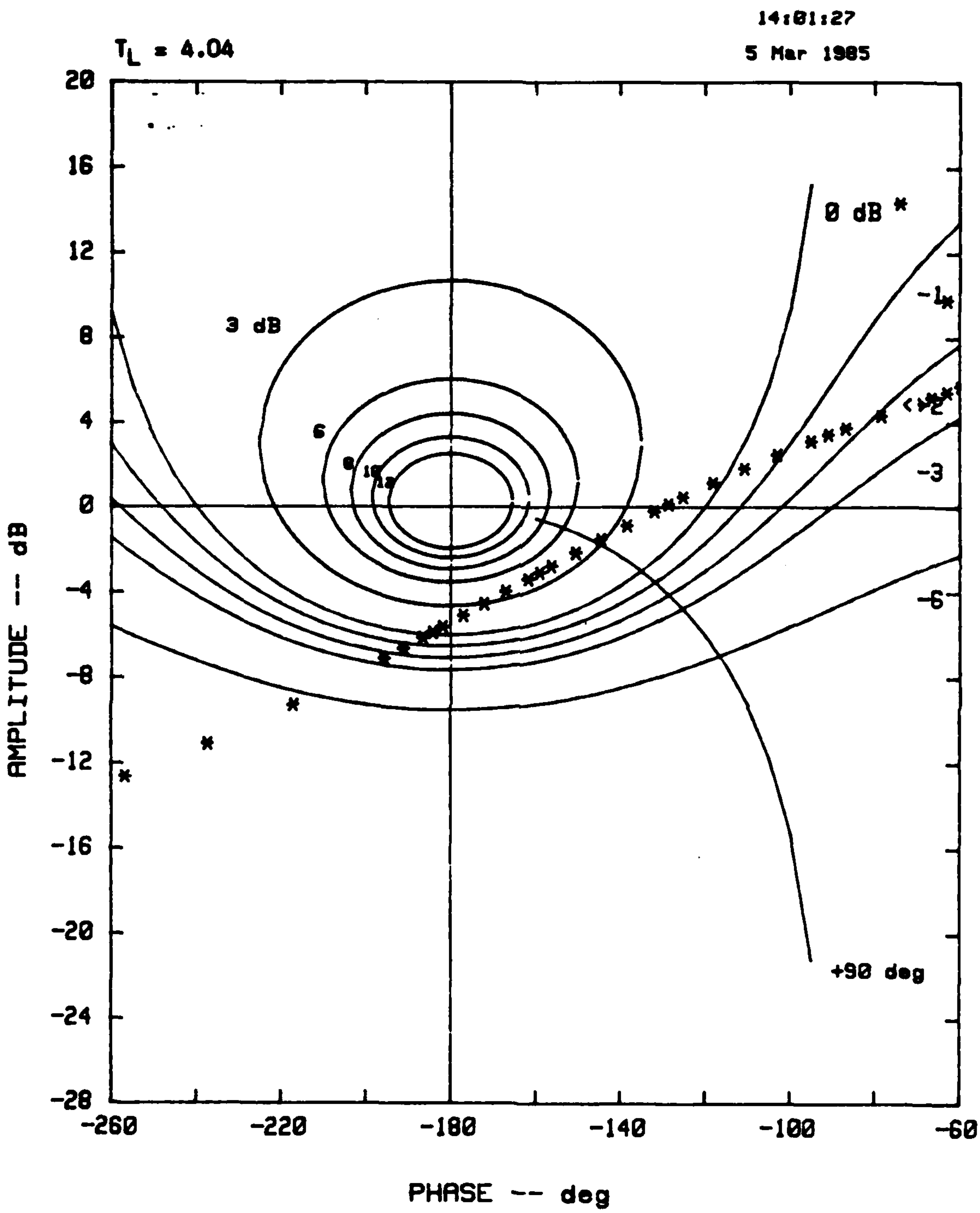


Figure F-30. NICHOLS CHART, CONFIGURATION C3-3, CLOSED LOOP BANDWIDTH: 3.0 r/s; PILOT TIME DELAY: .3 sec

Appendix G
TASK PERFORMANCE RECORDS

Included in this appendix are selected task performance records. The records were taken during the Head-Down pitch attitude tracking tasks using the ADI (see Section 4 for more detail).

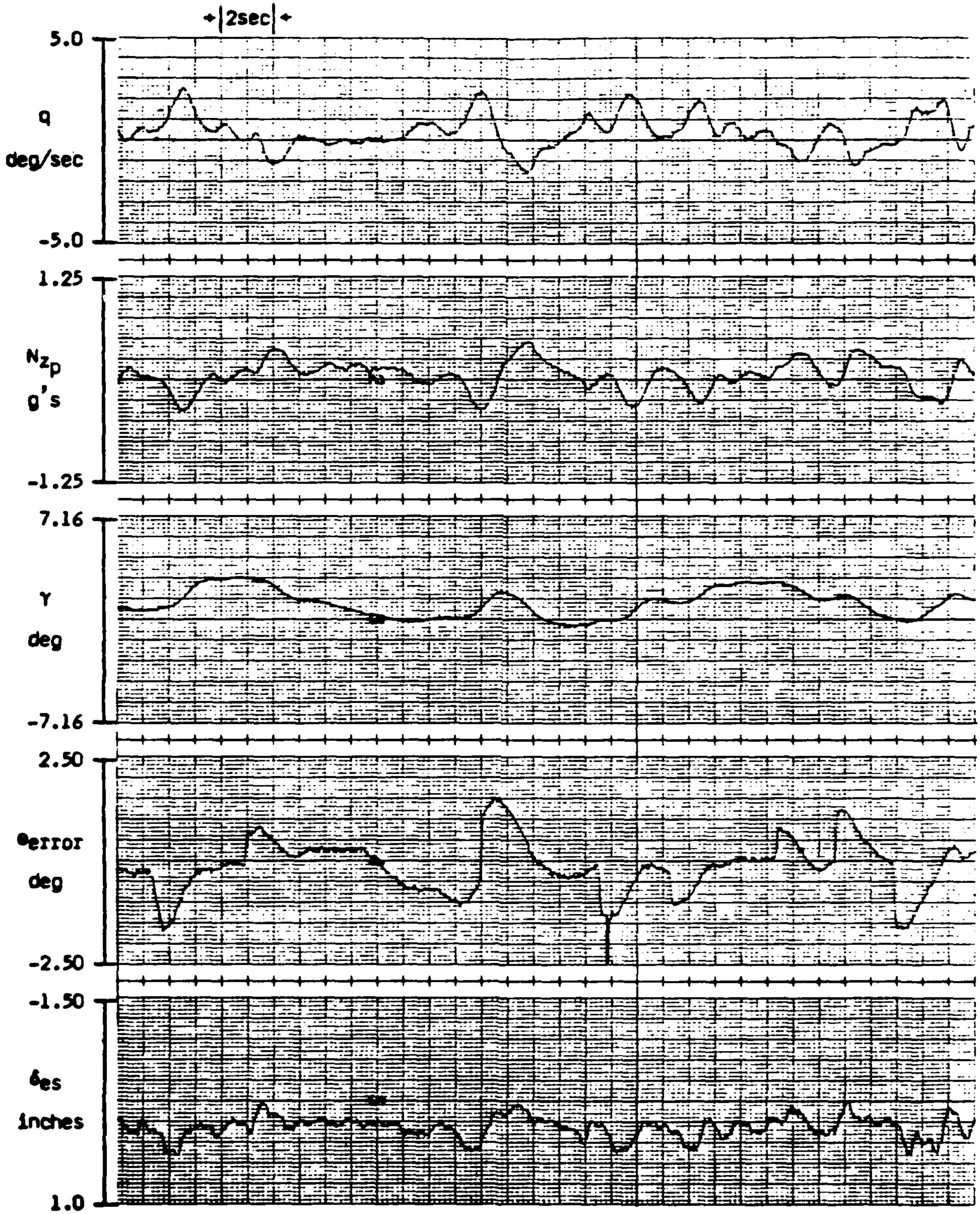


Figure G-1. TASK PERFORMANCE RECORD, CONFIGURATION C2-2x, FLIGHT 805, RECORD NO. 2

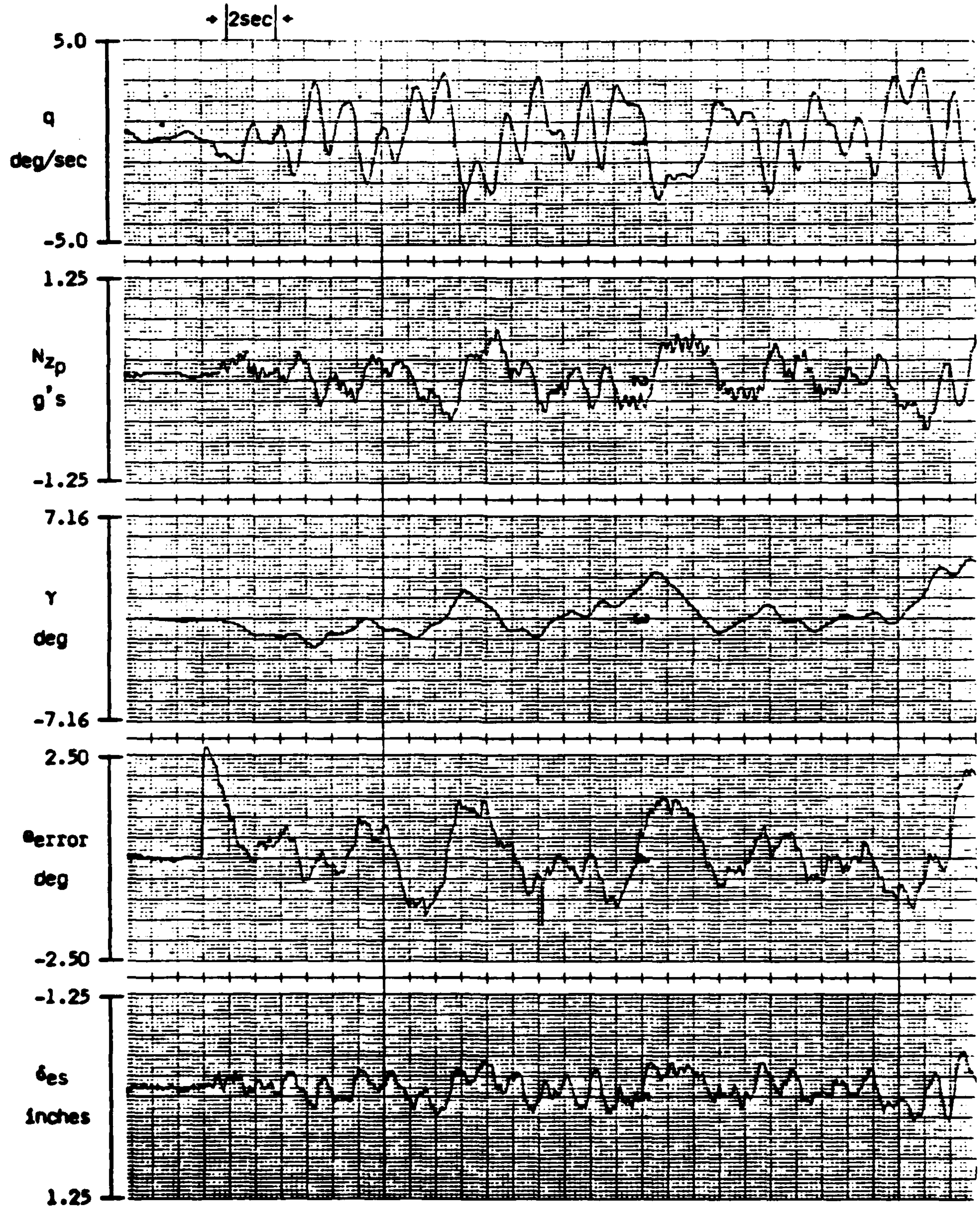


Figure G-2. TASK PERFORMANCE RECORD, CONFIGURATION B1-1, FLIGHT 804, RECORD NO. 24

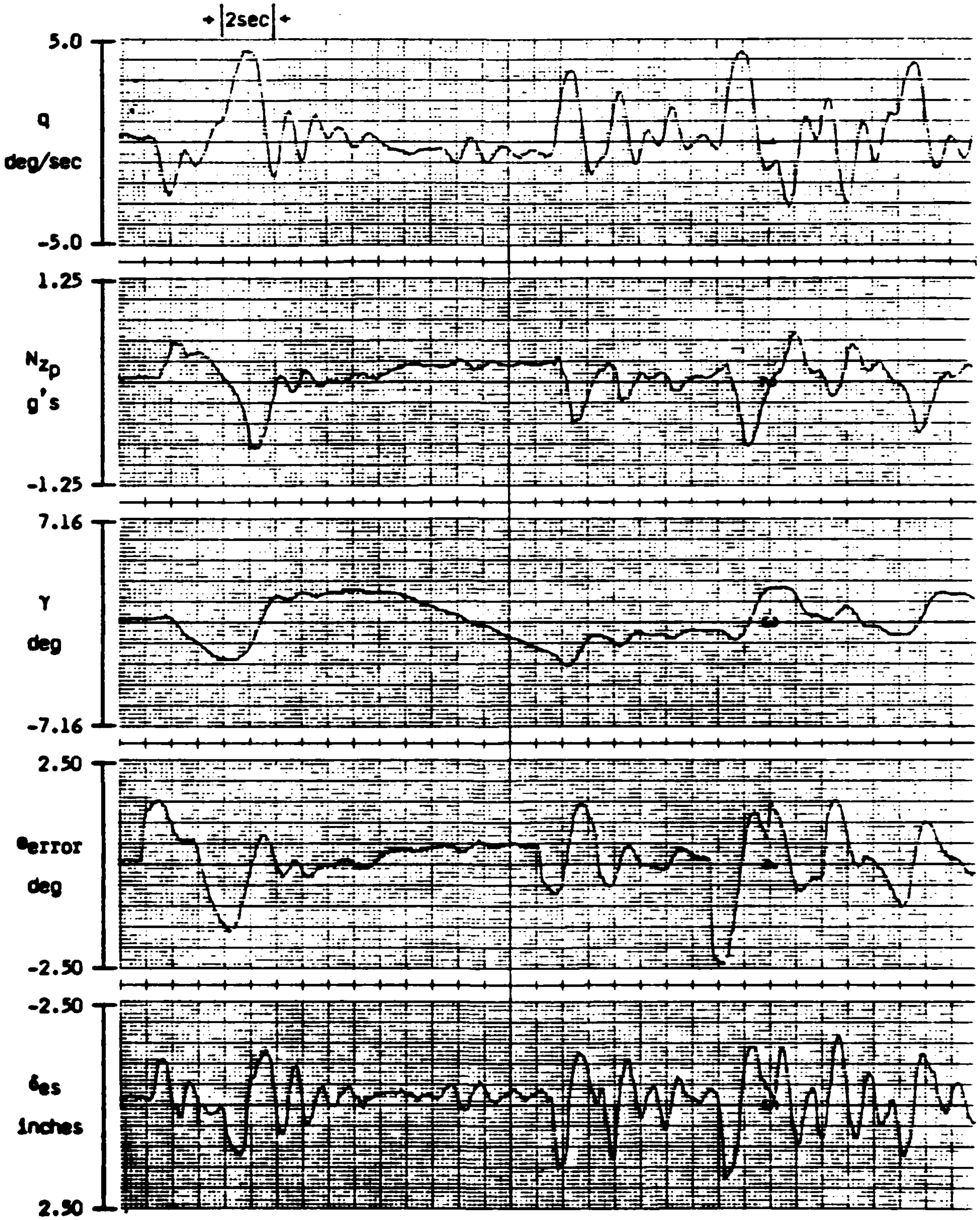


Figure G-3. TASK PERFORMANCE RECORD, CONFIGURATION B3-3, FLIGHT 804, RECORD NO. 06

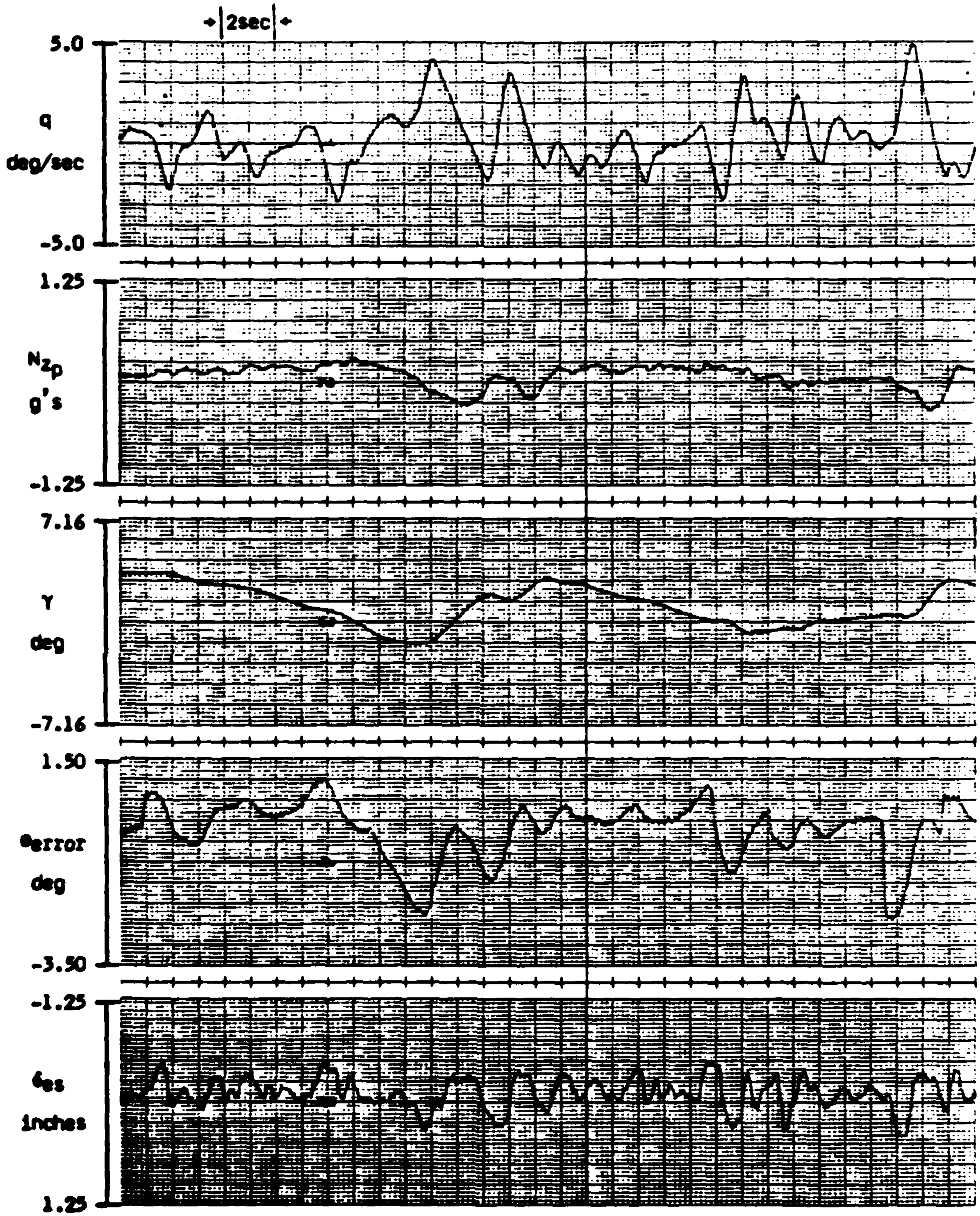


Figure G-4. TASK PERFORMANCE RECORD, CONFIGURATION A2-2x, FLIGHT 802, RECORD NO. 17

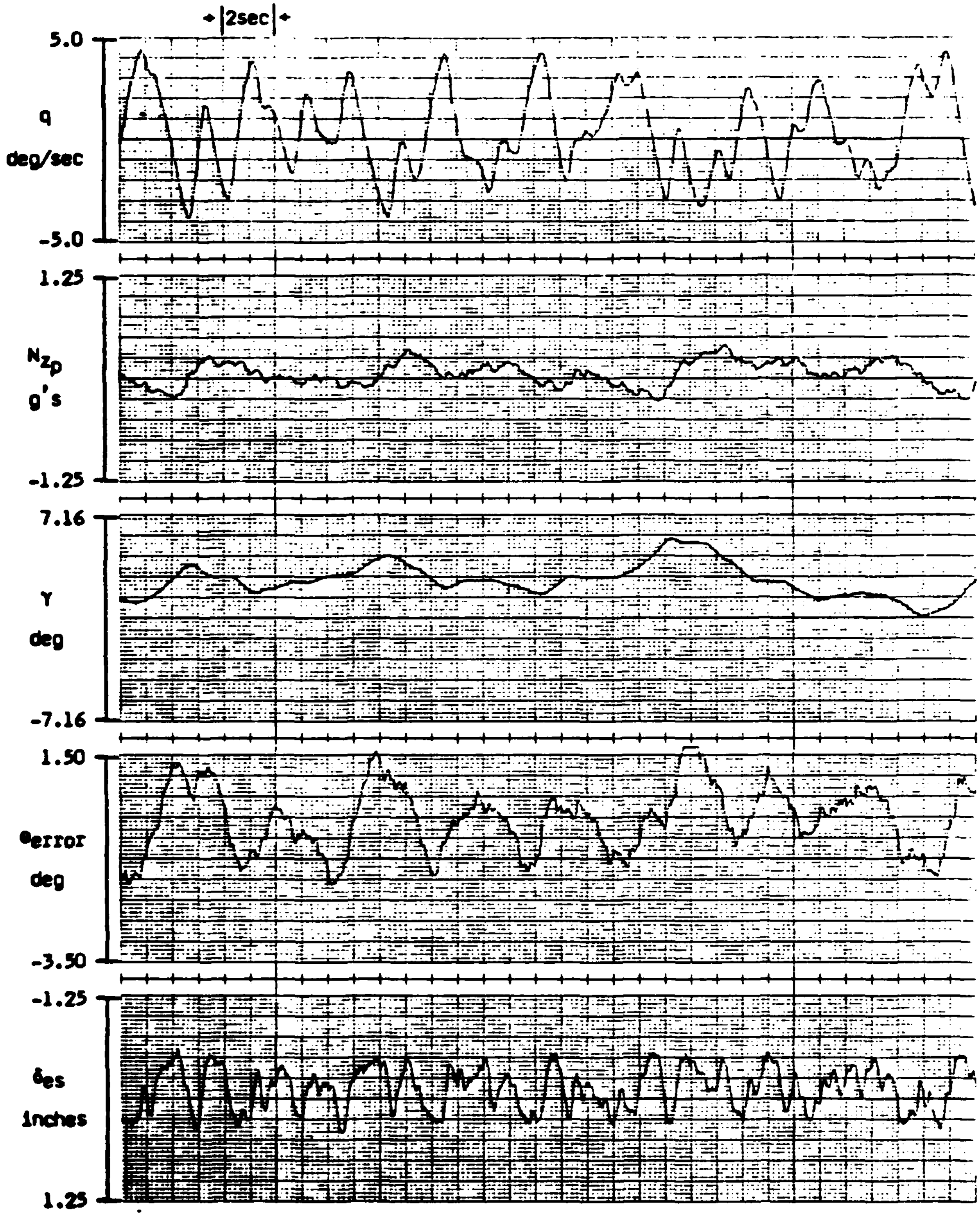


Figure G-5. TASK PERFORMANCE RECORD, CONFIGURATION A2-2x, FLIGHT 802, RECORD NO. 19

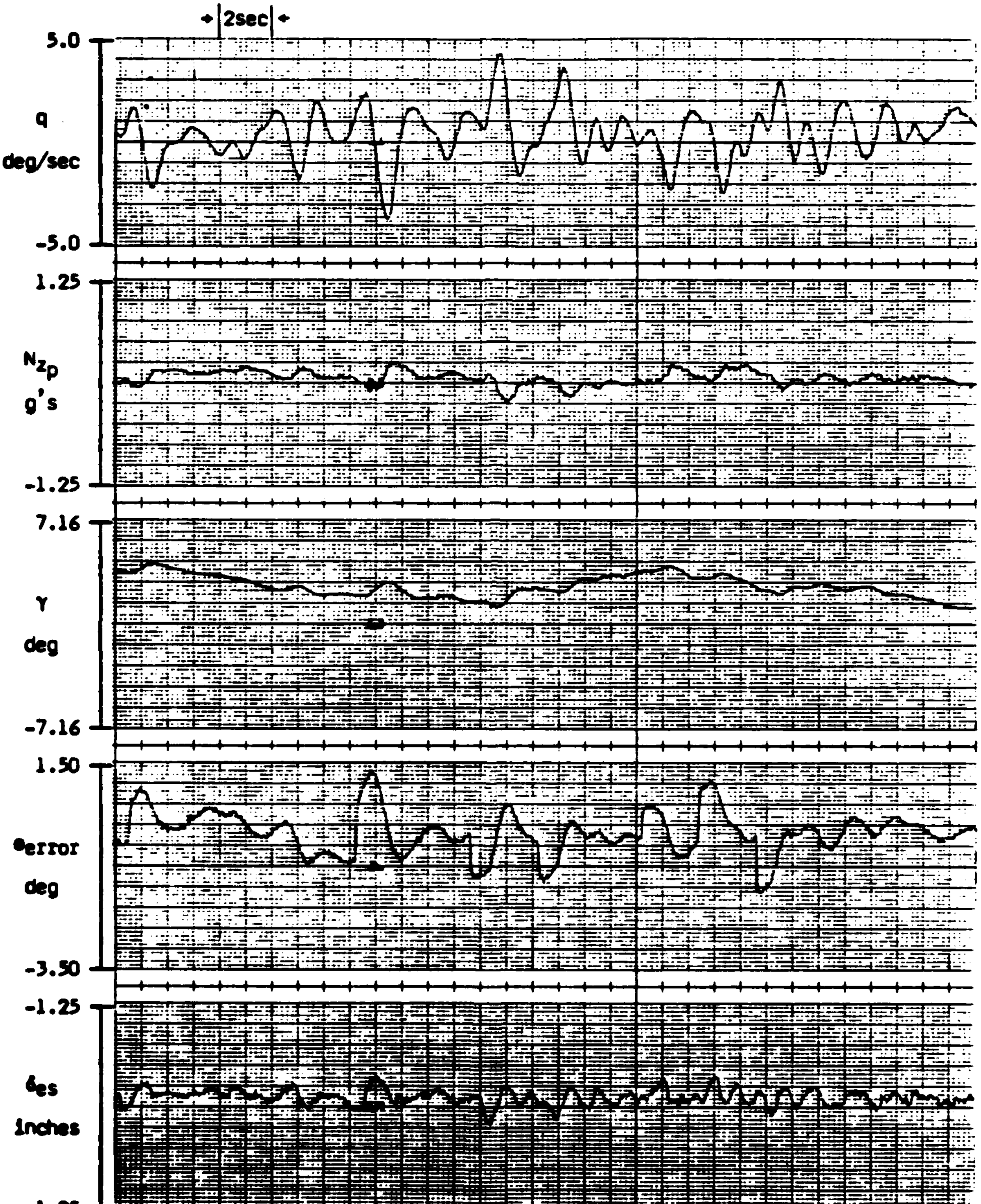


Figure G-6. TASK PERFORMANCE RECORD, CONFIGURATION A1-1, FLIGHT 802, RECORD NO. 09

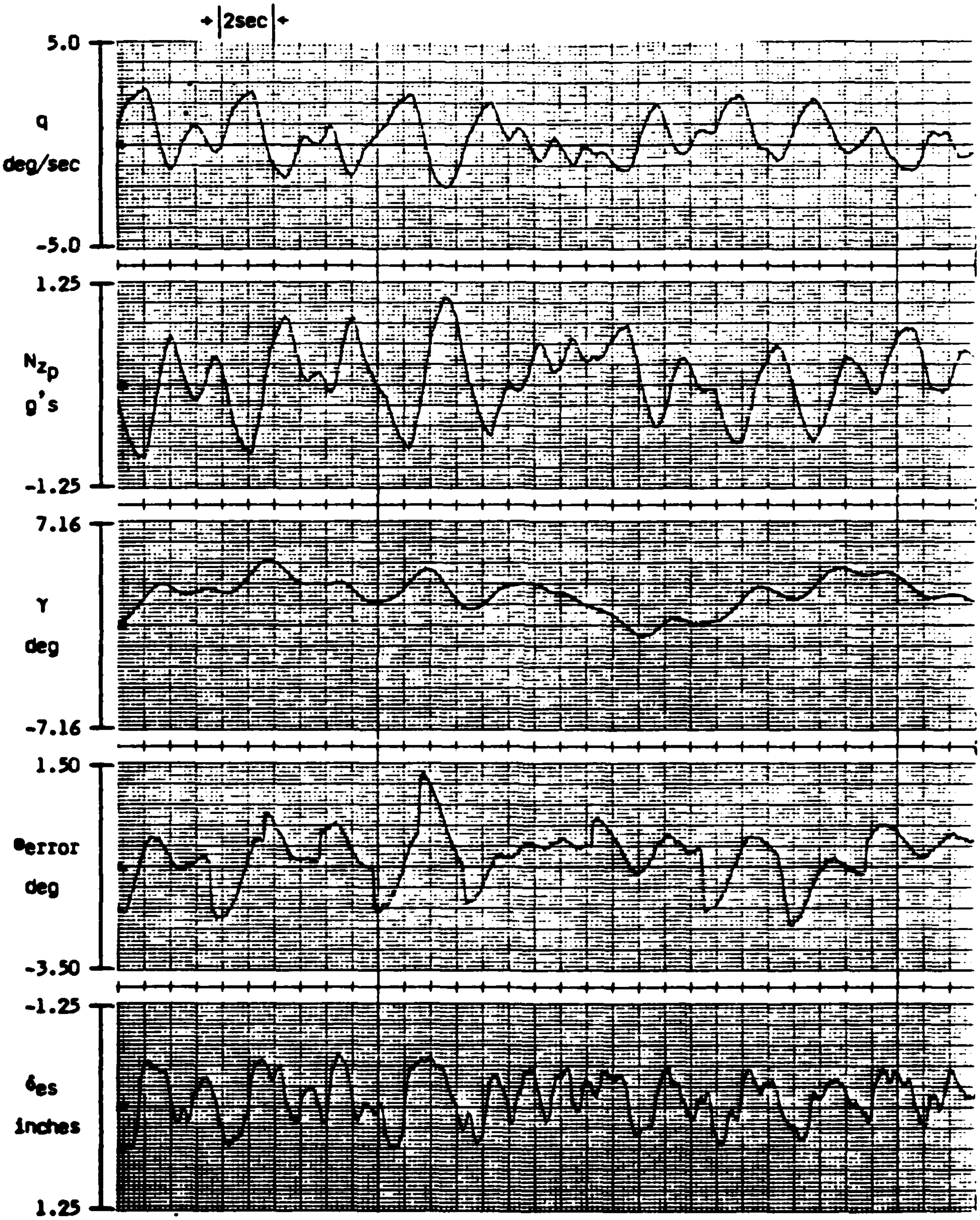


Figure G-7. TASK PERFORMANCE RECORD, CONFIGURATION C3-3x, FLIGHT 807, RECORD NO. 19

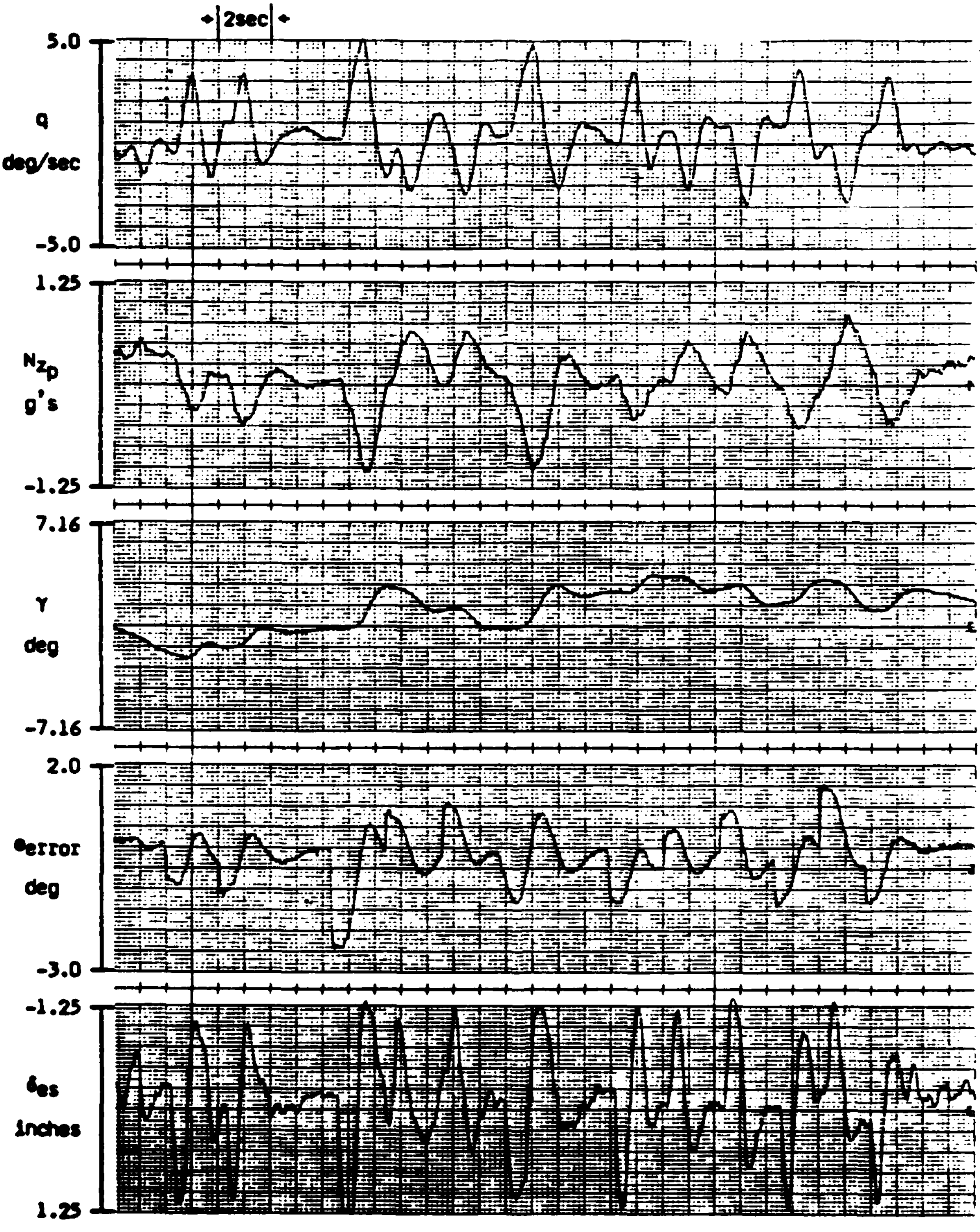


Figure G-8. TASK PERFORMANCE RECORD, CONFIGURATION B3-3x, FLIGHT 806, RECORD NO. 26

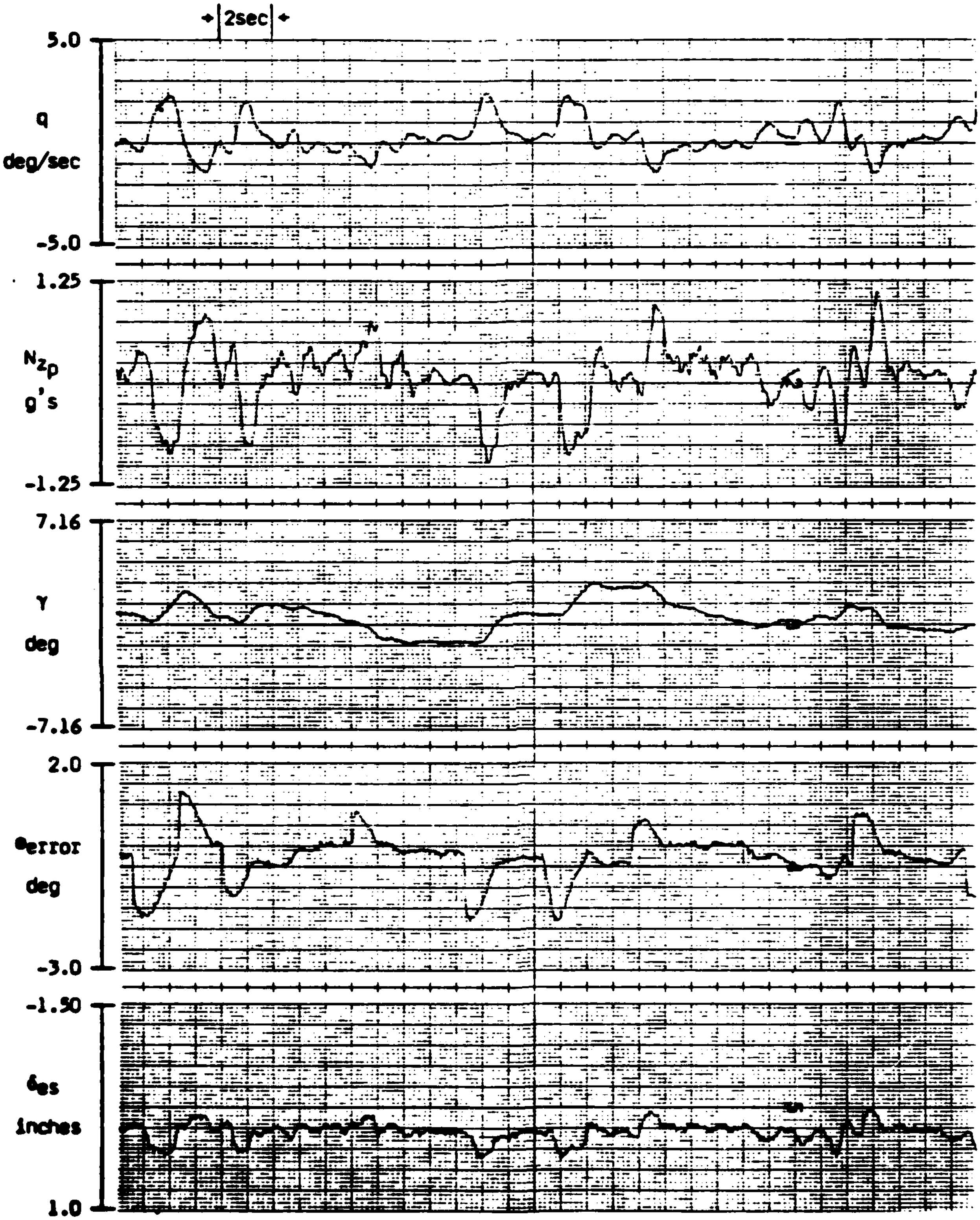


Figure G-9. TASK PERFORMANCE RECORD, CONFIGURATION C1-1, FLIGHT 807, RECORD NO. 07

Appendix H
PILOT COMMENT DATA

The pilot comment summaries are presented in this appendix. The title block for each evaluation contains pertinent configuration/evaluation data. The comment summaries were prepared from the complete tape recorded pilot comments.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
A1-1	802-2	A	8

Initial Remarks: Either a 7 or 8

Feel:

- Pitch Stick Forces: - didn't notice anything, no second thoughts
- Pitch Displacements: - not noticed
- Pitch/Roll Harmony: - adequate

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control:
  - initial response: - reasonable
  - predictability of final response: - variable; airplane gets "lumpy" when trying to fly in a closed-loop fashion - an over-control/PIO situation; however, amazing improvements in performance by open loop control--stops nicely with good speed of response
- Normal Acceleration:
  - initial response: - control almost impossible
  - predictability of final response: - poor; could not stop it when moving at a reasonable rate without overshoot (e.g. got 1 'g' when trying for ½ 'g' target)
- Special Pilot Techniques Used?: - if flown open-loop, quite reasonable pipper tracking performance; it slides and stops on a point rather well
- PIO Tendency: - PIO tendency which is very dependent upon pilot technique
- Task Differences: - sum of sines task exposed PIO tendency -- couldn't fly open-loop. ADI/discrete and visual tasks correlated well

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - not a factor
  - lateral-directional

Summary:

- Any Change in Rating? Cannot drive the airplane hard without getting into an overcontrol, PIO. Hard to judge with small 'g' band used here, but 'g' appeared to be divergent; controllability is in question, PR = 8. Very technique-sensitive airplane.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
A1-1X	803-1	A	7

Initial Remarks:

Feel:

- Pitch Stick Forces: - not noticed
- Pitch Displacements: - not noticed
- Pitch/Roll Harmony: - OK

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control:
  - initial response: - quick but
  - predictability of final response: - unpredictable
- Normal Acceleration: - non-existent control.
  - initial response:
  - predictability of final response: - could not precisely attain any 'g' level. very difficult to control
- Special Pilot Techniques Used?: - if not closed-loop, you can struggle to get adequate performance but very easy to oscillate airplane
- PIO Tendency:
- Task Differences: - ADI/discrete easier to fly than out-of-window stuff

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence
  - lateral-directional - no comments

Summary:

- Any Change in Rating? Not instinctive to fly; hard to know whether controllability is in question with some of these configurations in the sense of how much you would overcontrol the airplane.

{NOT USED IN ANALYSIS}

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
A1-1X	804-2	B	10

Initial Remarks: Not controllable within task limits (had 30 mil overshoot with 20 mil command); you could not look at this configuration without compensating after the very first look.

Feel:

- Pitch Stick Forces: - light, not too light
- Pitch Displacements:
- Pitch/Roll Harmony: - closely matched

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control: - sensitive in pitch, not abrupt or objectionable
  - initial response: - good, quick; at first, from initial response you think that pitch attitude control will be very good
  - predictability of final response: - large overshoot, cannot settle on target - PIO that, at times, seemed undamped
- Normal Acceleration:
  - initial response: - no perceptible response initially
  - predictability of final response: - not good because the 'g' catches up to you once the pipper is to the target in pitch - this couples and causes the PIO
- Special Pilot Techniques Used?: - initially to be smooth/not aggressive and then get out of loop to avoid oscillations around target
- PIO Tendency:
- Task Differences: - same things seen in all tasks

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - no influence
  - lateral-directional

Summary:

- Any Change in Rating? Hard to have a lot of confidence in rating due to simulation task limitations, but, by extrapolation the PIO's looked undamped.

(NOT USED IN ANALYSIS)

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
A2-2X	802-3	A	8

Initial Remarks: A lot of peculiarities depending upon which task you're doing. Not adequate performance for a fighter - PR =7.

Feel:

- Pitch Stick Forces: - could feel forces on occasion because I had tc overdrive airplane to get it going
- Pitch Displacements: - different gearing likely would not have helped, however
- Pitch/Roll Harmony: - roll noticeably more sensitive

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control: - couldn't get job done; oscillated 3-4 times around target
  - initial response: - slow, had to overdrive it to get reasonable fighter-type rates
  - predictability of final response: - poor
- Normal Acceleration: - extremely poor control of 'g'
  - initial response:
  - predictability of final response: - poor; had to back way down on the task to avoid overshooting very badly
- Special Pilot Techniques Used?: - very important / different techniques for different tasks
- PIO Tendency: - yes, when trying to fly it like a fighter.Got large amplitude, low frequency PIO
- Task Differences: - could do ADI/discrete task much better than out-the-window tracking - surprised me. did reasonable job with ADI/sum of sines once I quit going for the whole bundle at once - "incrementally" nulled error

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence
  - lateral-directional - not a factor

Summary:

- Any Change in Rating? Not a very good airplane. There is potential for over 'g' situation and low frequency PIO waiting to happen in visual target tracking, change rating to PR =8.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
A2-2X	803-5	A	8

Initial Remarks: Somewhat like previous one (A3-3X) - not half bad for small pointing exercises without 'g' loads, maybe a little sensitive. But very poor for flight path control; disconcerting, out of phase feeling leading to overcontrol.

Feel:

- Pitch Stick Forces:
- Pitch Displacements: - OK, maybe a little light
- Pitch/Roll Harmony: - good

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control: - pointing fine tracking capability only - satisfactory PR =3
  - initial response: - quick
  - predictability of final response: - predictable
- Normal Acceleration: - very poor; very easy to get out of phase
  - initial response:
  - predictability of final response: - large amplitude control poor
- Special Pilot Techniques Used?: - none noticed, except for backing away from task and not maneuvering aggressively
- PIO Tendency:
- Task Differences: - for 10 mil offsets, you can do it quickly and precisely. For 50 mil offsets, you get digging in and overcontrol. Somehow, sum of sines task seems to bring out the flight path-type control problems - e.g., digging in, out of phase, 'g' control problems

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence
  - lateral-directional - not a factor

Summary:

- Any Change in Rating? No change in rating.

(NOT USED IN ANALYSIS)

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
A3-3X	803-4		8

Initial Remarks: Very strange airplane - almost two different airplanes looking at pointing or attitude capability compared to normal acceleration control - overall rating is 8. Concerned about airplane digging in/over -'g'. Apprehension about being aggressive, building 'g' loads and reversing them.

Feel:

- Pitch Stick Forces: - a little on heavy side
- Pitch Displacements: - nothing noticed
- Pitch/Roll Harmony: - small harmony

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control: - good; pointing capability only: PR =3
  - initial response: - satisfactory
  - predictability of final response: - satisfactory
- Normal Acceleration: - really strange, easy to get out of phase
  - initial response: - big lag
  - predictability of final response:
- Special Pilot Techniques Used?: - apprehensive in 'g' tracking and sum of sines tasks
- PIO Tendency: - overcontrol in 'g', not attitude
- Task Differences: - normal acceleration problems did not show up in out of window or ADI/discrete tasks, but sum of sines gets you into a roller coaster 'g' change and you get an out-of-phase sensation coming thru

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence
  - lateral-directional - no factor

Summary:

- Any Change in Rating? Great pointing airplane but not maneuvering. Could get wildly out of phase in 'g' reversals.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
B1-1	804-3	B	5

Initial Remarks: Wanted to call it a 4; but for fine tracking performance, saw PI^ - giving a 5. Took compensation to settle on target.

Feel:

- Pitch Stick Forces: - good
- Pitch Displacements: - fine
- Pitch/Roll Harmony: - matched

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control:
  - initial response: - quick, crisp - seemed good
  - predictability of final response: - not too bad; didn't vary with command size or aggressiveness
- Normal Acceleration:
  - initial response: - a little abrupt; particularly noticeable in ADI/discrete and sum sines tasks. Felt like a kick in the pants during continuous closed-loop inputs.
  - predictability of final response: - OK, didn't feel like it would dig-in. Felt I had good control of 'g'.
- Special Pilot Techniques Used?: - lowered gain to combat PIO tendency in fine tracking but I didn't have to get out of loop to stop oscillations about target.
- PIO Tendency:
- Task Differences: - problem was settling down on target, 4-5 oscillations. If I stayed in loop during fine tracking tasks in sum of sines noticed a little discomfort with 'g' task.

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence
  - lateral-directional

Summary:

- Any Change in Rating? - not a bad configuration except for fine tracking task PIO tendencies.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
B1-1	805-3	A	2½

<u>Initial Remarks:</u> Highest bandwidth airplane I've had yet, best fighter airplane in terms of quickness of response with reasonable predictability. does have a little sharp-edgeness but also many admirable features. PR=3

<u>Feel:</u>

- Pitch Stick Forces: - on light side but not a factor
- Pitch Displacements: - OK
- Pitch/Roll Harmony: - good

<u>Aircraft Response Under Closed-Loop Control:</u>

- Pitch Attitude Control:
  - initial response: - quick and very quick compared to others
  - predictability of final response: - satisfactory
- Normal Acceleration: - in tune with pitch attitude
  - initial response: - quick
  - predictability of final response: - satisfactory
- Special Pilot Techniques Used?:
- PIO Tendency: - none
- Task Differences: - could perform tasks better than with any other configuration to this point

<u>Other Factors:</u>

- Any Factor in Evaluation due to:
  - turbulence - not a factor
  - lateral-directional - not a factor

<u>Summary:</u>

- Any Change in Rating? - changed rating to 2½

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
B1-1X	802-1	A	3

Initial Remarks:

Feel:

- Pitch Stick Forces: - requires some adaption to limit yourself to 1/2 g and try to assess overall stick forces; initially felt quite light but they were probably reasonable and good for gross maneuvering beyond (½) 'g' limit.
- Pitch Displacements: - not noticed
- Pitch/Roll Harmony: - no comments

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control: - one overshoot and on target for quick pipper movements
  - initial response: - quick
  - predictability of final response: - predictable
- Normal Acceleration:
  - initial response: - quick
  - predictability of final response: - not as predictable as pitch; tendency to have one big overshoot if I tried to move at same rate as attitude
- Special Pilot Techniques Used?: - none
- PIO Tendency: - none
- Task Differences: - sum of sine waves stuff may be useful to someone on ground but I cannot assess quality of performance using this task. Discrete ADI was a good task.

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - none
  - lateral-directional - none

Summary:

- Any Change in Rating? - no change in rating

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
B1-1X	806-2	B	8

Initial Remarks: Similar to Configuration Number 2 yesterday (A1-1X). Even in context of this task, control was in question; definitely when extrapolated to larger tasks.

Feel:

- Pitch Stick Forces: - light but liked them
- Pitch Displacements:
- Pitch/Roll Harmony: - mismatched a bit; roll forces heavier

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control: - precise for small acquisitions
  - initial response: - initial good/quick; not too much initial pitch overshoot; big overshoot came in N_z later
  - predictability of final response: - fairly predictable until correction attempted and then predictability degraded quite a bit
- Normal Acceleration:
  - initial response: - non-existent
  - predictability of final response: - very poor; that's where the controllability comes into question; 100% overshoot in 'g' captures
- Special Pilot Techniques Used?: - had to release stick to stop closed loop oscillations in corrections
- PIO Tendency: - tendency for closed loop oscillations around target; 4-6 overshoots under closed loop control
- Task Differences: - biggest problem with sum of sines task was closed loop oscillation; small amplitude but always out of phase. 'g' problems with large acquisition tasks

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - no
  - lateral-directional - no

Summary:

- Any Change in Rating? PR=8 because of large N_z overshoots (100%). No cues from initial N_z response and considerable pilot compensation required to minimize overshoot.

(NOT USED IN ANALYSIS)

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
B1-1X	807-1	A	2

Initial Remarks: Debating between a 2 and 2½. Right now give it a 2.

Feel:

- Pitch Stick Forces: - on the light side but comfortable
- Pitch Displacements: - not noticed
- Pitch/Roll Harmony: - good

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control:
  - initial response: - quick
  - predictability of final response: - predictability satisfactory; could settle the airplane down with two small overshoots even in the "simulated" gross acquisition
- Normal Acceleration:
  - initial response: - similar to pitch; pitch and N_z tied together nicely
  - predictability of final response: - could get a 'g' level and hold it in a reasonably predictable fashion.
- Special Pilot Techniques Used?: - none
- PIO Tendency: - none
- Task Differences: - tasks seem to be same in terms of difficulty discrete relates to fine tracking. sum of sines to maneuvering. performance same for all tasks.

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - none
  - lateral-directional - none

Summary:

- Any Change in Rating? Only problem was that it was a little quick and predictability suffered a tiny amount - but no compensation required. No change in rating.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
B1-2	808-1	B	3

Initial Remarks: Overall a fairly good airplane; felt like a normal airplane with a pretty good pitch attitude response and a little slower 'g' response. A couple of characteristics I wasn't crazy about.

Feel:

- Pitch Stick Forces: - good; maybe a tad sensitive
- Pitch Displacements: - OK
- Pitch/Roll Harmony: - not very well matched; roll response sluggish

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control: - fairly good but part of the reason I'm not real crazy about this configuration
  - initial response: - not so sluggish, it's fairly good/quick
  - predictability of final response: - suffers some, always an overshoot. More noticeable with agressiveness; took one to two oscillations to settle down on target
- Normal Acceleration:
  - initial response: - a little bit sluggish
  - predictability of final response: - suffers a little bit with .2 'g' overshoot on 'g' acquisitions
- Special Pilot Techniques Used?: - if 30-50 mils task, back off on agressiveness just a little bit and start taking input out as got closer to target to stop overshoot
- PIO Tendency: - just a little with aggressiveness
- Task Differences: - same performance with instrument and visual tasks. sum of sines performance not as good as other tasks because aggressiveness was necessary for this task but not able to with this configuration

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - none
  - lateral-directional - did not affect rating

Summary:

- Any Change in Rating? Got desired performance but didn't like increased overshoot and oscillations as pilot got aggressive - minimal pilot compensation required.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
B1-3	808-5	B	4

Initial Remarks: A different airplane. Overall I think I liked it. It had characteristics similar to airplanes that I've called 10 and 8 in the past but the PIO tendency is significantly reduced - a much, much better airplane - very nice in a lot of areas.

Feel:

- Pitch Stick Forces: - good, airplane seemed to be connected to stick
- Pitch Displacements: - fine
- Pitch/Roll Harmony: - not a problem

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control: - excellent especially for smaller amplitude pitch pointing
  - initial response: - excellent; not too abrupt, not too sensitive yet immediate response
  - predictability of final response: - very good
- Normal Acceleration: - a little bit of a lag in 'g' response that you could get out of phase and set up some sort of PIO tendency
  - initial response: - not as great as pitch, lagged
  - predictability of final response: - not very good, overshoot of .3 to .4 'g' noticed in larger tasks
- Special Pilot Techniques Used?: - for elevated 'g', had to get out of loop early to prevent oscillations about target
- PIO Tendency: - there is some tendency, but not strong. Problems caused by 'g' control.
- Task Differences: - visual tasks highlighted deficiencies most. could get out of phase in sum of sines task. very easy to do ADI/discrete (probably HQR = 1 or 2).

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - no factor
  - lateral-directional - no factor

Summary:

- Any Change in Rating? Tough rating - a real good airplane other than slight PIO tendency, PR=4; note however, that PIO tendency is not consistent with desired performance criteria, but PIO tendency is extrapolated to higher 'g' acquisitions. In the tasks performed, there was only a little PIO tendency if any, therefore PR = 4.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
B2-2	807-6	A	2

Initial Remarks: Good airplane; compared to the last one (C2-2) it doesn't stop as precisely or abruptly; it doesn't have that signature or "lump" in the end of the response as the last one did. The little abruptness helped, this one is smoother, more linear - really talking about degrees of goodness.

Feel:

- Pitch Stick Forces: - very good
- Pitch Displacements: - good
- Pitch/Roll Harmony: - good

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control:
  - initial response: - good
  - predictability of final response: - good
- Normal Acceleration:
  - initial response: - good
  - predictability of final response: - precise, predictable
- Special Pilot Techniques Used?: - none
- PIO Tendency: - none
- Task Differences: - tasks could be done equally well. Noticed again confidence to do sum of sine task.

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - no factor
  - lateral-directional - not a problem

Summary:

- Any Change in Rating? Clear-cut 2; in some respects better than last one in that it's smoother overall but it doesn't have the incredible precision in stopping without being bothersome in the 'g' spike at the cockpit.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
B2-3'	802-4	A	4

Initial Remarks: "Ponderous but precise"

Feel:

- Pitch Stick Forces: - really noticed forces, heavy in pitch
- Pitch Displacements: - with better gearing airplane would really be good
- Pitch/Roll Harmony: - very poor

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control: - you can achieve quite precise performance if you can put up with the heavy forces (fine tracking itself easily a 2)
  - initial response: - slow
  - predictability of final response: - extremely predictable
- Normal Acceleration: - could easily make .lg incremental changes with precision
  - initial response: - best I've seen yet, good speed of response
  - predictability of final response: - best I've seen yet, although forces tended to be on heavy side
- Special Pilot Techniques Used?: - overdriving airplane initially in pitch
- PIO Tendency: - none
- Task Differences: - interesting that ADI/discrete tracking correlated well with visual tracking. Hard to judge performance in sum of sines task but it does show different characters with different airplanes.

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence -
  - lateral-directional - not a factor

Summary:

- Any Change in Rating? Would like to see the airplane with more gearing. A little slow initially but very exact 'g' control very precise, fine tracking excellent.

((') = due to simulation mechanization error, the pitch gearing was such to produce a stick force gradient of 10.6 lbs per 'g' as opposed to the nominal 6.5 lbs/g)

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
B2-2X	803-2	A	2

Initial Remarks: Generally easy and instinctive airplane to fly.

Feel:

- Pitch Stick Forces: - no complaints
- Pitch Displacements: - not noticed
- Pitch/Roll Harmony: - good

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control: - good; fine tracking very good
  - initial response: -
  - predictability of final response: - very predictable; stopped where you wanted and flew in a linear fashion with stick
- Normal Acceleration: - good
  - initial response:
  - predictability of final response: - it was predictable
- Special Pilot Techniques Used?: - none required; easy to be in tune with airplane
- PIO Tendency: - none
- Task Differences: - consenus among tasks; you had your choice with how well you wanted to do with this airplane

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - not a factor
  - lateral-directional - OK

Summary:

- Any Change in Rating? - no change in rating

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
B2-2X	807-7	A	2

Initial Remarks: Seemed very similar to previous one (B2-2) - good airplane; easy to fly, instinctive. No deficiencies.

Feel:

- Pitch Stick Forces: - light, desirable
- Pitch Displacements: - no problem
- Pitch/Roll Harmony: - good

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control:
  - initial response: - good
  - predictability of final response: - predictable, good
- Normal Acceleration: - same as pitch
  - initial response: - good, smooth airplane
  - predictability of final response: - Predictable, precise
- Special Pilot Techniques Used?: - easy to fly
- PIO Tendency: - none
- Task Differences: - easy to do with consistent performance for all the tasks

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - none
  - lateral-directional - none

Summary:

- Any Change in Rating? Maybe a couple pipper widths for overshoots; I'm beginning to like the smoothness of this one as opposed to the little lump of Configuration C2-2. But I'm nit-picking - i-'s a very good airplane: PR=2

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
B2-2X	808-2	B	3

Initial Remarks: Fairly nice airplane; overall pretty good; level of deficiencies and performance comparable to last one (B1-2) but different things bothered me.

Feel:

- Pitch Stick Forces: - a little heavier than last one but comfortable - didn't affect the task at all.
- Pitch Displacements: - good
- Pitch/Roll Harmony: - OK

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control: - very good/well damped airplane
  - initial response: - fairly quick/ forces a little high and as a result, the airplane felt a tad sluggish but initial pipper movement pretty quick
  - predictability of final response: - real good, as long as input was not very large. Could stop with little or no oscillation about target
- Normal Acceleration:
  - initial response: - lagging a little bit
  - predictability of final response: - suffered a little bit with .2 'g' overshoot. Normal acceleration response looked similar to last configuration.
- Special Pilot Techniques Used?: - tendency to overdrive larger acquisition
- PIO Tendency: - none unless large inputs then maybe oscillate once or twice
- Task Differences: - easier with ADI/discrete than visual because of smaller commands

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - no factor
  - lateral-directional - no factor

Summary:

- Any Change in Rating? Very good configuration except it was a little bit sluggish for larger inputs (>30 mils). As a result tended to overdrive and oscillate around target. Actually liked it a little better than last one. PR =3: had to compensate for larger inputs.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
B3-3	804-1	B	7

Initial Remarks:

Feel:

- Pitch Stick Forces: - high forces
- Pitch Displacements: - OK
- Pitch/Roll Harmony: - poor, pitch forces higher

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control:
  - initial response: - sluggish
  - predictability of final response: - not bad onto itself, but uncomfortable with 'g' response; caused pilot compensation
- Normal Acceleration:
  - initial response: - didn't seem to be any
  - predictability of final response: - poor
- Special Pilot Techniques Used?: - did not want to be aggressive with airplane in sum of sines task with 'g' overshoot
- PIO Tendency: - yes, in gross acquisition tasks
- Task Differences: - for 50 mil offset, saw 30 mil overshoot with 4-6 oscillations. The larger the command/target, the larger the overshoots; task performance not bad for small targets; rating would have been much better for this alone

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence -
  - lateral-directional - no factor

Summary:

- Any Change in Rating? - overall rating of a 7

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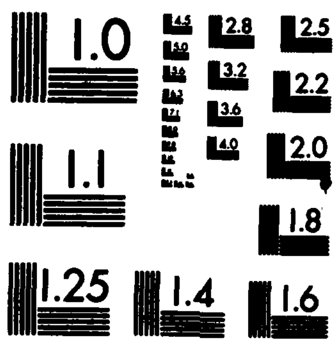

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Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
B3-3	805-2	A	8

Initial Remarks: Very strange airplanes; two distinctly different airplanes between attitude and normal acceleration control. Would have doubts about controllability if aggressive for large amplitude maneuvers.

Feel:

- Pitch Stick Forces: - didn't notice anything
- Pitch Displacements: - OK
- Pitch/Roll Harmony: - a little more sensitive in roll than pitch

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control:
  - initial response:
  - predictability of final response:
- Normal Acceleration:
  - initial response:
  - predictability of final response:

- just in fine tracking or small discrete tracking without flight path or 'g' changes, the configuration is really amazing - you can move pipper quite quickly and it stops exactly where you want it - very precise. For pitch/fine tracking, PR=1 However, had an eerie feeling about airplane for large or gross changes - strange 'g' feeling which was totally out of synch with what you were trying to do.

- Special Pilot Techniques Used?: - had to back way off for gross acquisitions because you felt you were going to get out of phase quickly
- PIO Tendency: - with aggressiveness, would have 'g' PIO
- Task Differences: - problems showed up in large maneuvers and ADI/sum of sines(gross acquisition correlates well with ADI/sum of sines) (fine tracking and ADI/discrete correlate well with some of the larger discretes showing gross acquisitio[n] type deficiencies)

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - no factor
  - lateral-directional - nothing noted

Summary:

- Any Change in Rating? Might be a 10 due to overcontrol if large amplitude, large 'g' fighter maneuvers attempted.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
B3-3X	803-3	A	4

Initial Remarks: Desired performance but some deficiencies were there.

Feel:

- Pitch Stick Forces: - heavy side, would like them lighter
- Pitch Displacements: - noticed occasionally
- Pitch/Roll Harmony: - not perfect, heavier in pitch

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control:
  - initial response: - a little slow
  - predictability of final response: - very predictable; you could move it, over-drive it and still keep same performance; maybe one overshoot to target
- Normal Acceleration: - good, but hard to assess speed of response as well as I would like in small confines of simulation task
  - initial response:
  - predictability of final response: - overall, satisfactory
- Special Pilot Techniques Used?: - none noticed
- PIO Tendency: - no PIO
- Task Differences: - no great differences

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence
  - lateral-directional - not a factor

Summary: Pilot rating of 4 (minor but annoying deficiencies) because of:

- Any Change in Rating?
  - heavy forces
  - something about airplane that feels a little "unnatural" - not totally instinctive like last airplane (B2-2X) but performance quite good. Desired performance easily achieved. Something that wasn't quite normal about pitch and normal acceleration response - not a big problem but noticeable.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
B3-3X	806-4	B	4

Initial Remarks:

Feel:

- Pitch Stick Forces: - good but a little high
- Pitch Displacements: - OK
- Pitch/Roll Harmony: - roll was quicker than pitch

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control:
  - initial response: - somewhat sluggish; on lower end of what I would like
  - predictability of final response: - as a result of sluggish, some pitch overshoots; no problem for small acquisitions/ saw overshoot for larger maneuvers. Easy to fine-track with airplane.
- Normal Acceleration:
  - initial response: - somewhat sluggish; could be compensated for
  - predictability of final response: - .3 'g' overshoot; N_z at cockpit seemed to lift you out of your seat a little bit
- Special Pilot Techniques Used?: - pitch and N_z required some compensation
- PIO Tendency: - not too much except for larger acquisitions
- Task Differences: - noticed pitch sluggish more in ADI tasks than in visual tasks.

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - no
  - lateral-directional - no

Summary:

- Any Change in Rating? Pilot compensation was overdriving in pitch and being aware that pitch and N_z will overshoot; compensation was to get input out to keep N_z overshoot small.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
C1-1	807-2	A	5

Initial Remarks: Strange airplane in many ways; best described as "lumpy but accurate"; accelerations at cockpit very abrupt; pilot rating either 4 or 5. Could achieve desired performance. Call it a 4.

Feel:

- Pitch Stick Forces: - comfortable but light
- Pitch Displacements: - not noticed
- Pitch/Roll Harmony: - pitch more sensitive than roll - no big problem

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control: -
  - initial response: - good
  - predictability of final response: - very predictable; could stop it wherever you wanted it. A consequence was a bump in N_z at cockpit
- Normal Acceleration: - abrupt
  - initial response: - too quick
  - predictability of final response: - it was predictable; could get 'g' levels and hold them but just overly abrupt
- Special Pilot Techniques Used?: - excited a structural mode on occasion. Just relaxed control for a moment to alleviate it. Not a factor in tasks or evaluation.
- PIO Tendency: - none
- Task Differences: - could do everything with level of quickness or standard of performance as high as any configuration seen

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - not a factor
  - lateral-directional - not noticed

Summary:

- Any Change in Rating? Liked performance but didn't like the ride - got stunning performance (desired performance) but I like the word "moderately objectionable deficiencies." Too abrupt at cockpit.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
C1-1	808-3	B	6

Initial Remarks: Strange airplane/deceptive in that you could do some of the tasks fairly well but it wasn't comfortable at all and certainly not good for most tasks.

Feel:

- Pitch Stick Forces: - not too bad; initially sensitive, but in steady-state maneuvers, the forces are a tad high yet not too high
- Pitch Displacements: - not bad
- Pitch/Roll Harmony: - pitch sensitivity seemed high

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control: - for small tasks, pretty good
  - initial response: - very quick
  - predictability of final response: - within context of small task to keep system on line, was not too bad; for larger tasks that were performed, the steady-state pitch response does not keep up and is not near as quick as initial. Airplane feels more sluggish and then you have to be more aggressive. Initial sensitivity keeps you from aggressiveness and a dicotomy results.
- Normal Acceleration:
  - initial response: - very quick but in steady-state, seems to slow down
  - predictability of final response: - very predictable; no more than .1 'g' overshoot
- Special Pilot Techniques Used: - tendency to be less aggressive because of abruptness
- PIO Tendency: -
- Task Differences: - noticed problems in visual task with larger commands and in sum of sines task

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - none
  - lateral-directional - none

Summary:

- Any Change in Rating? In context of what we were doing, adequate performance was attainable with tolerable pilot workload. The problem is that the pilot really had to back off for aggressive or larger acquisitions due to abruptness at the cockpit.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
C2-2	805-5	A	2

Initial Remarks: Overall a pretty good airplane - it is an airplane like this that the simulation constraints on 'g' really bother you because pitch attitude and 'g' are correlated nicely together in a standard airplane like fashion and the forces are light, but fighter-like, so you have to back away a bit in gross acquisition part of simulation.

Feel:

- Pitch Stick Forces: - good
- Pitch Displacements: - no problem
- Pitch/Roll Harmony: - good

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control:
  - initial response: - satisfactory
  - predictability of final response: - satisfactory
- Normal Acceleration: - similar to pitch/in consonance with it. When I pulled back I got attitude changes and normal acceleration changes in a fashion I'm used to. Could control both accurately.
  - initial response:
  - predictability of final response: -
- Special Pilot Techniques Used?: - no special techniques
- PIO Tendency: - no PIO tendency
- Task Differences: - out of window tracking good - moved quite smartly to target. Discrete error was easy to do. Could keep up with the sum of sines task at the maximum rates that I've been able to achieve.

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - not a factor
  - lateral-directional -

Summary:

- Any Change in Rating? Just a little abruptness in the airplane that reminded me of the other airplane I flew (B1-1) - this is a characteristic of a responsive airplane when doing the task. Clearly a satisfactory airplane.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
C2-2	806-3	B	6

Initial Remarks: Deceptive airplane; very good for small acquisitions and pitch pointing/fine tracking with no PIO-tendency.

Feel:

- Pitch Stick Forces: - good
- Pitch Displacements: - OK
- Pitch/Roll Harmony: - matched well

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control: -
  - initial response: - a little bit sluggish
  - predictability of final response: - some overshoot; don't see full extent of overshoot until larger acquisitions, then large pitch overshoots
- Normal Acceleration:
  - initial response: - very quick for all tasks - probably would have been good except it occurs right here at cockpit and felt as a heaving motion - ride qualities suffer
  - predictability of final response: - predictability suffers from mismatch with sluggish pitch attitude during visual tasks
- Special Pilot Techniques Used?: - none required for small maneuvers; have to compensate for pitch overshoot in large maneuvers
- PIO Tendency: - a little tendency for large maneuvers
- Task Differences: - small acquisition no problem (Level 1). For >30 mil tasks, N_z response is immediate, but pitch attitude isn't then problems with pitch tracking

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - none
  - lateral-directional - none

Summary:

- Any Change in Rating? - want to smooth out inputs because N_z at cockpit is abrupt; then poor task performance because of sluggish pitch response
  - No change in rating

(NOT USED IN ANALYSIS)

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
C2-2	807-5	A	1½

Initial Remarks: Extremely good airplane; just a little "lump" when stopping. It was an airplane you could build a lot of confidence in and fly in the context of our limited task envelope as aggressively as any. It is noticeable most in sum of sine waves task in confidence to pushover and follow task. In others you just can't do that. Clear-cut 2.

Feel:

- Pitch Stick Forces: - light but satisfactory
- Pitch Displacements: - no problem
- Pitch/Roll Harmony: - good

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control:
  - initial response: - good
  - predictability of final response: - outstanding; could be consistent between gross and fine tracking; hardly any discernible overshoots
- Normal Acceleration:
  - initial response: - precise
  - predictability of final response: - predictable; it stopped with a little signal/a little bump in the 'g' that told you it stopped and it was going to stay there
- Special Pilot Techniques Used?: - none
- PIO Tendency: - none
- Task Differences: - same level of performance in all tasks

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - no factor
  - lateral-directional - no factor

Summary:

- Any Change in Rating? Maybe a little better than a 2; clearly in the best category I've seen; change to a 1½.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
C2-2X	805-1	A	3

Initial Remarks: Pitch and normal acceleration were very similar and in harmony in that they went along together - with a pitch attitude change, I got a 'g' change.

Feel:

- Pitch Stick Forces: - satisfactory
- Pitch Displacements: - not a factor
- Pitch/Roll Harmony: - good

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control:
  - initial response: - satisfactory
  - predictability of final response: - satisfactory
- Normal Acceleration:
  - initial response: - satisfactory
  - predictability of final response: - satisfactory
- Special Pilot Techniques Used?: - none used
- PIO Tendency: - none
- Task Differences: - fine tracking (PR=2) - easy. Discrete/ADI - easy to do. Sum of sines was easy to do because I was in phase with 'g'. One area it fell down a bit was in large acquisitions, got maybe one overshoot of 5 mils

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence
  - lateral-directional

Summary:

- Any Change in Rating? Instinctive to fly; felt in phase with pitch and normal acceleration - airplane seemed to point and change flight path at same time. PR = 3 for a little extra work to settle pipper down during large acquisitions.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
C2-2X	807-3	A	8

Initial Remarks: Strange airplane (what were system characteristics and what were real characteristics?); peculiar in gross maneuvers where it was delayed when you try to move it quickly and then it would spring up and really accelerate/overshoot. Consequently, overcontrol and PIO - seemed nonlinear.

Feel:

- Pitch Stick Forces: - don't remember
- Pitch Displacements:
- Pitch/Roll Harmony: - no comments

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control: - attitude control for small displacements good
  - initial response: - good
  - predictability of final response: - good/predictable
- Normal Acceleration: - reasonable
  - initial response:
  - predictability of final response: - predictable
- Special Pilot Techniques Used?: - tended to back away from airplane during corrections to avoid nonlinear behavior
- PIO Tendency:
- Task Differences: - sum of sines related to gross maneuver/overcontrol problem and backed away from it

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - none
  - lateral-directional - none

Summary:

- Any Change in Rating? Not a nice "clean" airplane to evaluate due to system problems - judging from what I saw it had major deficiencies. Fine tracking satisfactory (PR=2) however overall PR of 8. If strange characteristics were real, not system problems, then serious damage could be caused.

(NOT USED IN ANALYSIS)

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
C2-2X	808-4	B	7

Initial Remarks: Didn't like this one. You can't be aggressive with this airplane and have predictability.

Feel:

- Pitch Stick Forces: - not too bad
- Pitch Displacements: - not too bad
- Pitch/Roll Harmony: - pitch more sluggish than roll; somewhat mismatched

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control:
  - initial response: - lagged input quite a bit
  - predictability of final response: - very poor; wasn't as noticeable for small inputs but for 50 mil task, airplane had a classic "digging-in" tendency and PIO potential about target
- Normal Acceleration:
  - initial response: - tended to go right along with pitch attitude
  - predictability of final response: - suffered somewhat; didn't notice any real problems with normal acceleration; seemed like an attitude control problem
- Special Pilot Techniques Used?: - had to overdrive airplane for large tasks and figure out a way to get the input out -- almost impossible without overshooting target
- PIO Tendency:
- Task Differences: - saw problems more in visual than instrument. saw "re-correction" problem in sum of sines tasks where, if you aggressively tried to correct overshoot, you got multiple oscillations about target with fairly large, uncomfortable 'g' increments

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - no
  - lateral-directional - no

Summary:

- Any Change in Rating? More than tolerable pilot workload. No PIO. Control still not in question

(NOT USED IN ANALYSIS)

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
C3-3	804-4	B	5

Initial Remarks: Not desired performance for overall task - particularly for gross acquisition ~100% overshoot. Had to cut aggressiveness in pitch for large maneuvers.

Feel:

- Pitch Stick Forces: - high, a little too high
- Pitch Displacements: - noticeable at times
- Pitch/Roll Harmony: - some roll sensitivity

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control: - a little sluggish; have to overdrive airplane
  - initial response: - sluggish
  - predictability of final response: - good for small acquisitions one overshoot at most; poor predictability for larger commands
- Normal Acceleration:
  - initial response:
  - predictability of final response: - seems to be slow; for large acquisitions, I didn't seem to notice any response until the pipper was about at target and then normal acceleration came in and seemed to cause overshoot
- Special Pilot Techniques Used?: - none at all for fine tracking; had to smooth out inputs after initially overdriving airplane in large acquisitions
- PIO Tendency: - none; even for large acquisitions, airplane would settle down with one overshoot
- Task Differences: - sum of sines difficult because of pitch sluggishness and high stick forces; over-control tendency. Good performance in ADI/discrete. General maneuvering was difficult for large maneuvers.

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence -
  - lateral-directional - no factor

Summary:

- Any Change in Rating? - Level 1 airplane for fine tracking.
  - Noticed problems for large acquisition maneuvers. If you don't do the large acquisition maneuvers, it looks like a good airplane, but it's not.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
C3-3	805-4	A	7

Initial Remarks: Strange airplane; out of phase with pitch and in phase with normal acceleration. Had a weird feel about it. Could not achieve adequate performance in gross acquisition or fine tracking.

Feel:

- Pitch Stick Forces: - heavy; airplane slow, drifting
- Pitch Displacements: - OK
- Pitch/Roll Harmony: - off a little bit

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control: - at times, it almost seemed like my control was reversed when I tried to do anything rapidly
  - initial response: - airplane seemed slow, although you could get it started
  - predictability of final response: - problem was stopping airplane; airplane floated around a little bit. Predictability poor.
- Normal Acceleration: - if concentrated on normal acceleration by itself, I was able to do a satisfactory job - although the sum of sines task, which previously had correlated well with 'g' control, seemed to be more difficult.
  - initial response:
  - predictability of final response:
- Special Pilot Techniques Used?: - could not find one to work.
- PIO Tendency: - ponderous PIO tendency in pitch
- Task Differences: - saw PIO tendency in sum of sines task. Did better on discrete task than I thought I was going to. Correlation of tasks to quality of performance in attitude or 'g' control seemed to be different than any I've seen.

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - sometimes present but not a factor
  - lateral-directional - not a factor

Summary:

- Any Change in Rating? Didn't like airplane / strange unusual reaction to controls. Wasn't going to over-'g' airplane, just couldn't put it where I wanted it.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
C3-3	806-1	B	4

Initial Remarks: Felt a little sluggish. Pitch forces a little higher than I would like; airplane essentially a pretty good pitch pointer with exception of pitch overshoot (about 50%) for large acquisitions; good airplane for fine tracking and small acquisitions.

Feel:

- Pitch Stick Forces: - little high; gearing affected task a little bit
- Pitch Displacements: - OK
- Pitch/Roll Harmony: - pitch heavier than roll

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control: - not bad but not great either
  - initial response: - somewhat sluggish; combination of gearing and airplane being slow to get started
  - predictability of final response: - not real bad but there was pitch overshoot; most noticeable in larger acquisition tasks especially sum of sines task.
- Normal Acceleration: - overall, it wasn't too bad
  - initial response: - didn't seem too bad
  - predictability of final response: - good; .1 'g' overshoot in 'g' captures
- Special Pilot Techniques Used?: - had to overdrive airplane because of sluggish pitch response
- PIO Tendency: - saw maybe one "extra" oscillation in larger tasks but didn't feel like much of a PIO tendency
- Task Differences: - had much easier time with ADI/discrete than ADI/sum of sines; sluggish pitch response required overdriving response and continual sum of sines target caused overcontrol problems

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - none
  - lateral-directional - none

Summary:

- Any Change in Rating? No change / PR=4 primarily for pitch sluggishness and slow aircraft response in pitch. Good fine tracking airplane.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
C3-3X	807-4	A	7

Initial Remarks: "Ponderous but imprecise"; slow and can't overdrive to get performance because of overshooting, overcontrol and PIO. Overshoots even in fine tracking.

Feel:

- Pitch Stick Forces: - heavy at times, don't think you can change a whole lot by changing the gearing
- Pitch Displacements: - noticeable at times trying to speed up response
- Pitch/Roll Harmony: - roll quicker

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control:
  - initial response: - slow
  - predictability of final response: - poor; especially for larger maneuvering. can't stop it/ it seems to have a mind of its own; it drifts by target no matter what you do.
- Normal Acceleration:
  - initial response: - reasonable
  - predictability of final response: - not good; oscillations in N_z seemed to be of higher frequency. I couldn't sustain steady 'g'
- Special Pilot Techniques Used?: - tried to overdrive airplane for performance but then performance suffered; no compromise
- PIO Tendency: - PIO in pipper tracking, low frequency
- Task Differences: - adequate performance in ADI/discrete. Had eerie feeling of getting out of phase with sum of sines, especially coming over the top; had to back off task.

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - none
  - lateral-directional - none

Summary:

- Any Change in Rating? No control problems, it's just so slow; not a comfortable/ instinctive airplane to fly.

Configuration	Flight No. - Evaluation	Pilot	Pilot Rating
C3-3X	808-6	B	7

Initial Remarks: Didn't particularly like this airplane; predictability problems. Adequate performance could be attained but an awful lot of anticipation is required by pilot to catch overshoot and settle it down. Workload was greater than tolerable.

Feel:

- Pitch Stick Forces: - at first forces seemed heavy, but steady-state fairly light; did not influence task
- Pitch Displacements: - OK
- Pitch/Roll Harmony: - more sluggish in pitch yet forces seemed well matched

Aircraft Response Under Closed-Loop Control:

- Pitch Attitude Control: - not very sensitive
  - initial response: - sluggish
  - predictability of final response: - poor, particularly if you set up higher rates
- Normal Acceleration:
  - initial response: - seemed pretty good
  - predictability of final response: - predictable; not a problem
- Special Pilot Techniques Used?: - considerable compensation to start taking out overdriven input way before pipper got to target and to keep from overshooting too far
- PIO Tendency: - not really a PIO tendency, just overshoots
- Task Differences: -

Other Factors:

- Any Factor in Evaluation due to:
  - turbulence - no factor
  - lateral-directional

Summary:

- Any Change in Rating? Not satisfied with airplane.

REFERENCES

1. Flight Research Department: "Total In-Flight Simulator (TIFS) -Preliminary Design Report", AFFDL-TR-71-119, August 1971.

2. Reynolds, P.A. et al.: "Capability of the Total In-Flight Simulator (TIFS)", AFFDL-TR-72-39, July 1972.

3. Berthe, C.J.; Chalk, C.R. and Sarrafian, S.: "Pitch Rate Flight Control Systems in the Flared Landing Task and Design Criteria Development", NASA-CR-172491, October 1984.

4. Hodgkinson, J.: "The Application of Equivalent Systems to MIL-F-8785B", Presented at the Flying Qualities Symposium and Workshop, Wright-State University, Dayton, Ohio, MCAIR 79-015, 12-15 September 1978.

5. Hoh, R.H., Mitchell, D.G., and Hodgkinson, J.: "Bandwidth - A Criterion for Highly Augmented Airplanes", paper presented at AGARD Flight Mechanics Panel Symposium Criteria for Handling Qualities of Military Aircraft, Fort Worth, Texas, April 1982.

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